Total Maximum Daily Loads for the Hanalei Bay Watershed

PHASE 1 – Streams and Estuaries

September 2008

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List of Abbreviations

BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMP	Best Management Practice
C-CAP	Coastal Change Analysis Program
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEM	Digital Elevation Model
EFDC	Environmental Fluids Dynamic Code
Entero	Enterococcus
EPO	(Hawai'i State Department of Health) Environmental Planning Office
GIS	Geographic Information System
HAR	Hawai'i Administrative Rules
HIDOH	Hawai'i State Department of Health
HSPF	Hydrologic Simulation Program – Fortran
KGD	Kilograms Per Day
LA	Load Allocation
LSPC	Loading Simulation Program in C++
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NCDC	National Climatic Data Center
NH_4	Ammonia
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrite Plus Nitrate
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTE	Not to Exceed
NTU	Nephelometric Turbidity Units
#/day	Number Per Day
NWR	National Wildlife Refuge
SSC	Suspended Sediment Concentration
SSM	Single Sample Maximum
STATSGO	State Soil Geographic Database
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
Toolbox	TMDL Modeling Toolbox
TP	Total Phosphorous
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQC	Water Quality Criteria
WQLS	Water Quality Limited Segment

Acknowledgements

This rationale document, prepared by the State of Hawaii Department of Health, Environmental Planning Office (DOH-EPO), incorporates and expands upon the 2007 draft "Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed" prepared for U.S. Environmental Protection Agency (EPA) Region 9 and DOH by Tetra Tech, Inc. We gratefully acknowledge the efforts of the Tetra Tech team led by Amy King, Andrew Parker, and John Craig with key technical assistance from Rui Zou and Sen Bai; the analytical work of their subcontractor AECOS, Inc; and extensive data and on-site assistance from the Hanalei Watershed Hui, the U.S. Geological Survey Pacific Water Science Center, and the U.S. Fish and Wildlife Service (Hanalei Wildlife Refuge and Pacific Region Division of Engineering, Water Resources Branch). Other supporting organizations and individuals included the Institute of Pacific Islands Forestry (U.S. Department of Agriculture, Forest Service), the U.S. Geological Survey Western Coastal and Marine Geology Program, U.S. Department of Agriculture Natural Resources Conservation Service, the University of Hawaii Water College of Tropical Agriculture and Human Resources, Neil Berg, Carl Orazio, and our DOH colleagues throughout the Environmental Health Administration, particularly the Environmental Health Analytical Services Branch staff (State Laboratories Division), the Polluted Runoff Control Program (Clean Water Branch), and Gary Ueunten (Clean Water Branch Monitoring and Analysis Section, Kauai District Health Office).

This work was funded by EPA Region 9, EPA Water Pollution Control and Polluted Runoff Control program grants to DOH (Clean Water Act §106 and §319), and by State budgeting for staff positions and office support within DOH.

Executive Summary

The State of Hawaii Department of Health (DOH) proposes establishing a total of eight (8) Total Maximum Daily Loads (TMDLs) for streams and estuaries in the Hanalei Bay Watershed on the island of Kauai, Hawaii. TMDLs are required for pollutant-impaired water bodies on the State's Clean Water Act (CWA) Section 303(d) list. The primary objectives of the proposed TMDLs are to stimulate and guide action that will control sources of excessive nutrients, sediment, and pathogens, and to improve the water quality of the inland waters (streams and estuaries) so that the designated and existing uses of waterbodies throughout the Hanalei Bay watershed will be protected and sustained. These uses include protection of native breeding stock; the support and propagation of aquatic life, shellfish, and other marine life; conservation of coral reefs and marine wilderness areas; recreation; aesthetic enjoyment; and support for traditional and customary native Hawaiian beliefs, values, and practices.

Ongoing water quality monitoring and assessment efforts point to sediments, nutrients, and microbial pathogens as the pollutants of concern in this watershed. In response to the 2006 List of Impaired Waters in Hawai'i Prepared under Clean Water Act (CWA) §303(d), DOH proposes Total Maximum Daily Loads (TMDLs) for total suspended solids (TSS; TSS is included as a surrogate for turbidity TMDLs) in Hanalei Stream and Hanalei Estuary (together defined as the Hanalei Stream System), Waipa Stream and Estuary (Waipa Stream System), and in the Waioli, Waipa, and Waikoko Estuaries (Table ES-2); and for and *enterococci* in the Hanalei Stream System (table ES-3). Implementing these sediment and bacteria TMDLs will result in the attainment of water quality criteria for turbidity and *enterococcus* in the Hanalei Stream System and for turbidity in the other nearby streams and estuaries in the Hanalei Bay watershed.

DOH also calculated Informative TMDLs and Load Targets (both not for EPA approval) to help guide nonpoint source pollution management efforts (Tables 16 through 26). Table ES-1 identifies the §303(d) listings, exceedances based on data analyses, and how the waterbody-pollutant combination was addressed in this current study (TMDL, informative TMDL, or Load Target). DOH proposes a phased approach to the ongoing development and implementation of TMDLs throughout the Hanalei Bay watershed, so that new information obtained in the next phases of the TMDL process can be used to revisit impairment decisions, load allocations, and implementation strategies and tactics.

Federal regulations and guidance require that the State of Hawai'i Department of Health (HIDOH) allocate the approved TMDLs between point source discharges regulated under discharge permit (Waste Load Allocations) and nonpoint source runoff that is not regulated by discharge permit (Load Allocations). However, since no MS4 (Municipal Separate Storm Sewer System) or other individual National Pollutant Discharge Elimination System (NPDES) permits for point sources have been issued covering Hanalei receiving waters, this report only provides Load Allocations (LAs) for nonpoint source runoff in the Hanalei watershed. If Waste Load Allocations (WLAs) are required to accommodate future point source discharges, then the LAs would have to be revised and the overall changes in the TMDL allocations would have to be approved by the U.S. Environmental Protection Agency (USEPA).

Table ES-1. Summary of Listings, Exceedances, and Current Application (Table 10)

Waterbody	Description	Entero	Turbidity	NH4	NOx	TN	TP	TSS
Estuary								
Hanalei River Estuary	Included on 2006 303(d) list[a]	Y	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	**TMDL**	**Verification**	IT	IT	IT	IT	**TMDL**
Waioli Stream Estuary	Included on 2006 303(d) list[a]	N	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waipa Stream Estuary	Included on 2006 303(d) list[a]	N	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	—	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waikoko Stream Estuary	Included on 2006 303(d) list[a]	N	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Stream								
Hanalei Stream	Included on 2006 303(d) list[a]	Y	**D**	N	N	N	N	N
	Criteria exceeded[b]	√	W/D		—	W	W	W
	Current application[c]	**TMDL**	**Verification**	LT	IT	IT	IT	**TMDL**
Waioli Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	—	LT	IT	IT	IT	IT
Waipa Stream	Included on 2006 303(d) list[a]	N	**D**	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	**Verification**	LT	IT	IT	IT	**TMDL**
Waikoko Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	no data		no data	no data	no data	no data
	Current application[c]	IT	—	LT	IT	IT	IT	IT

[a]Y = year-round impairment; **D** = dry season impairment; **W** = wet season impairment; N = not listed

[b]For estuaries, exceedances are associated with year-round criteria (√). For streams, *enterococcus* is associated with year-round criteria (√), but all other parameters have separate wet (W) and dry (D) season standards that can be exceeded. These letters indicate that one or more of the applicable WQC were exceeded (additional details regarding these exceedances are presented in Table 11. Shading indicates no applicable standard. Waterbody-pollutant combinations not exhibiting any exceedances in the available data are represented by "–."

[c]**TMDL** = TMDLs were calculated as part of the current application; **Verification** = data and model output were used to confirm impairments and/or verify attainment of WQC through TSS TMDL implementation; IT = Informative TMDLs were calculated as part of the current application. LT = Load Targets were calculated as part of the current application; Waterbody-pollutant combinations not specifically addressed by any loading calculations are represented by "–."

The Hanalei Bay watershed is a 32.3 square-mile area draining to Hanalei Bay along the north shore of Kaua'i, including the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream watersheds (Figure 1). The Hanalei River watershed is the largest of these watersheds, making up 73.2% of the Hanalei Bay drainage area (23.6 square-miles). The Waioli Stream watershed is the second largest drainage area with nearly 5.5 square-miles, followed by the 2.5 square-mile Waipa Stream watershed and the 0.7 square-mile Waikoko Stream watershed.

The watershed originates at the summit of 5,240 foot Mount Wai'ale'ale, which receives an average of 450 inches of rainfall per year, while the coastal areas receive less than 100 inches of rainfall annually (University of Hawai'i, 2002, and see Figure 2). Much of the rainfall occurs during the wet season from November through April. Hanalei has a tropical climate with an average annual temperature in the mid-seventies and an average humidity in the low eighties (Weather Underground, 2006). The rainfall patterns tend to follow the elevation contours in the region, with higher rainfall occurring in the higher elevations. Many of the higher elevation areas also have very steep slopes.

The Halelea Forest Reserve makes up a majority of the headwaters area (see Figure 4). Agriculture, grassland, and urban areas also drain into the Hanalei River and other tributaries that eventually discharge to the Hanalei Bay (Figure 3). In addition, the 16 mile Hanalei River, which was designated an American Heritage River in 1998, passes through the Hanalei National Wildlife Refuge (NWR), which includes taro pondfields and several bird impoundments. The urban areas, which make up less than 1% of the land area, are primarily located in Hanalei town center along the Kuhio Highway (University of Hawai'i, 2002).

Water quality monitoring data for streams, estuaries, and drainage culverts (see Figure 5) were compared to the water quality criteria (WQC), evaluated spatially, analyzed for correlations, and compared with stream flow measurements at the United States Geological Survey (USGS) stream flow gage (station 1610300). These analyses support the sediment and bacteria impairments as well as other sediment, bacteria, and nutrient concerns in the watershed. Available data were also used to configure, calibrate, and validate a customized modeling framework developed to support *enterococcus* and turbidity TMDLs as well as the Informative TMDLs and Load Targets. This framework consists of a series of watershed models (based on the Loading Simulation Program in C++ [LSPC]) and a receiving water model (based on the Environmental Fluids Dynamic Code [EFDC]). The watershed models predicted pollutant loadings for each of the four primary watersheds draining to Hanalei Bay, while the receiving water model of the estuaries and Hanalei Bay simulated water circulation and pollutant transport in the tidally-influenced waterbodies.

The models were configured using key datasets to represent hydrology, hydrodynamics, and land practices in the Hanalei Bay watershed. These datasets, which include watershed boundaries, meteorological data, land cover, soils, reach characteristics, water quality data, bathymetry, and circulation and tidal data, were incorporated into the LSPC or EFDC models during model setup. The LSPC model was then calibrated and validated for both hydrology and water quality for May 2001 – May 2006. Model results were compared to flow and water quality data during this process. The loads from the LSPC model were then incorporated into the EFDC model of the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, Waikoko Stream Estuary, and the Hanalei Bay. The EFDC model was then calibrated and validated for hydrodynamics and water quality for 2004-2005 by comparing the model results to observed data. Both the LSPC and EFDC models achieved good fit between modeled and observed results.

Output from the LSPC and EFDC models were used to determine existing loads based on current conditions as well as TMDLs for the *enterococcus* and turbidity impaired waterbodies and Informative TMDLS and Load Targets for other waterbody-pollutant combinations in the Hanalei Bay watershed. The TMDL values were compared against existing loads to determine the load reductions necessary to meet the water quality criteria. LSPC model output was also used to assess land cover-specific contributions to the total existing watershed load for each pollutant.

Specific measures for reducing pollutant loads, improving water quality, and repairing and protecting aquatic ecosystems in the Hanalei watershed may be found in the Hanalei Watershed Action Plan and other Hanalei Watershed Hui planning documents; U.S. Fish and Wildlife Service Refuge Management Plan; State of Hawai'i forest management plans; soil and water conservation plans for agricultural lands; watershed-based plans and TMDL implementation plans prepared or accepted by the HIDOH; and other government and private planning initiatives. By incorporating the LA objectives presented below, activities that take action to reduce pollutant loading may unlock the door to additional Clean Water Act §319(h) incremental funds (administered by HIDOH) for water quality improvement projects.

Contributing sources and load allocations of the Hanalei Stream System TMDLs for TSS and *enterococcus* are summarized in the tables presented below, along with the load reductions required to achieve these allocations. These tables present the TMDLs associated with all applicable WQC (geometric mean, 10% not-to-exceed, and 2% not-to-exceed WQC for TSS and 30-day geometric mean and single sample maximum WQC for *enterococcus*) and are also presented by wet and dry (calendrical) seasons, although only the stream standards vary by season. Estuary TMDL results are based on achieving the year-round estuary standards. The annual load results are presented seasonally to maintain consistency with the stream TMDLs and for implementation purposes.

With regard to implementing the bacterial TMDLs, in general DOH does not consider chronic exceedances of *enterococcus* criteria to unequivocally represent threats to human health or impairments of recreational use. Before taking action to implement bacterial indicator TMDLs, it is important to acquire more conclusive evidence that human sewage or human-pathogenic organisms are present at levels that indicate an unacceptable public health risk. According to the DOH on-site disposal system strategy and water quality monitoring strategies, any implementation activities conducted should first focus on inventory and inspection of sanitary sewer collection systems and individual wastewater systems; repairing and upgrading failing and sub-standard systems (as indicated by inspection results); and completing watershed sanitary surveys and wastewater source tracking to complement information obtained from system inventory/inspection and ambient receiving water monitoring.

This TMDL decision rationale reviews historical and existing conditions in the Hanalei Bay watershed and presents an analysis of pollutant load distributions and resulting water quality in streams and estuaries (inland waters) of the Hanalei, Waioli, Waipa, and Waikoko stream systems. We provide calculations of waterbody pollutant loading capacities, and of their allocations to identified pollutant sources such that water quality standards for turbidity and enterococcus would be achieved. Thus implementing these pollutant load allocations is expected to contribute to the achievement of State water quality goals throughout the watershed.

If WLAs are required to accommodate future point source dischargers, the State will assure implementation of approved TMDL WLAs through the enforcement of NPDES permit conditions (HAR §11-55). The State will pursue implementation of LAs through Hawai'i's Implementation Plan for Polluted Runoff Control (HIDOH, 2001), Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (State of Hawai'i, 1996), and Watershed-based Plans and TMDL Implementation Plans that address the nine elements required by USEPA guidance for awarding additional Clean Water Act §319(h) incremental funds (USEPA, 2003a). Watershed Based Plans and TMDL Implementation Plans are expected to incorporate the LA objectives from the tables below and Table 14 and Table 15 in Section 7.3 of this report.

In the following tables summarizing the proposed TMDL decision (ES-2 and ES-3):

- TMDL allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366).

- Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,
(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

- Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

*Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows).

Acronyms: LA = Load Allocation

MOS = Margin of Safety

TMDL = Total Maximum Daily Load

kgd = kilograms per day

Table ES-2 Wet and Dry Season TMDL Allocations to Existing Sources and Load Reductions Required to Achieve Hanalei Stream and Estuary Turbidity Standards (Table 14)

Total Suspended Solids						
Wet Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1431.3	75.3	1506.6	6550.7	5044.0	77.0%
Hanalei River Estuary	1520.6	80.0	1600.6	6959.2	5358.6	77.0%
Waioli Stream Estuary	117.5	6.2	123.7	1124.9	1001.1	89.0%
Waipa Stream	49.5	2.6	52.1	452.8	400.7	88.5%
Waipa Stream Estuary	53.7	2.8	56.5	491.6	435.1	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	110.8	108.4	97.8%
Wet Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2220.0	116.8	2336.8	6550.7	4213.9	64.3%
Hanalei River Estuary	2358.4	124.1	2482.5	6959.2	4476.7	64.3%
Waioli Stream Estuary	187.5	9.9	197.4	1124.9	927.4	82.5%
Waipa Stream	63.3	3.330	66.6	452.8	386.2	85.3%
Waipa Stream Estuary	68.7	3.6	72.3	491.6	419.3	85.3%
Waikoko Stream Estuary	3.9	0.2	4.1	110.8	106.7	96.3%
Wet Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2894.1	152.3	3046.4	6550.7	3504.3	53.5%
Hanalei River Estuary	3074.5	161.8	3236.4	6959.2	3722.9	53.5%
Waioli Stream Estuary	318.2	16.8	334.9	1124.9	789.9	70.2%
Waipa Stream	59.8	3.147	62.9	452.8	389.8	86.1%
Waipa Stream Estuary	64.9	3.4	68.3	491.6	423.3	86.1%
Waikoko Stream Estuary	6.3	0.3	6.7	110.8	104.1	94.0%
Dry Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1415.8	74.5	1490.3	6479.5	4989.2	77.0%
Hanalei River Estuary	1504.1	79.2	1583.2	6883.6	5300.4	77.0%
Waioli Stream Estuary	116.3	6.1	122.4	1112.6	990.2	89.0%
Waipa Stream	48.9	2.6	51.5	447.9	396.4	88.5%
Waipa Stream Estuary	53.1	2.8	55.9	486.3	430.4	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	109.6	107.2	97.8%
Dry Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2195.8	115.6	2311.4	6479.5	4168.1	64.3%
Hanalei River Estuary	2332.8	122.8	2455.6	6883.6	4428.0	64.3%
Waioli Stream Estuary	185.5	9.8	195.3	1112.6	917.4	82.5%
Waipa Stream	62.6	3.294	65.9	447.9	382.0	85.3%
Waipa Stream Estuary	67.9	3.6	71.5	486.3	414.7	85.3%
Waikoko Stream Estuary	3.8	0.2	4.0	109.6	105.6	96.3%
Dry Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2862.6	150.7	3013.3	6479.5	3466.2	53.5%
Hanalei River Estuary	3041.1	160.1	3201.2	6883.6	3682.4	53.5%
Waioli Stream Estuary	314.7	16.6	331.3	1112.6	781.3	70.2%
Waipa Stream	59.2	3.113	62.3	447.9	385.6	86.1%
Waipa Stream Estuary	64.2	3.4	67.6	486.3	418.7	86.1%
Waikoko Stream Estuary	6.3	0.3	6.6	109.6	103.0	94.0%

Table ES-3. Wet and Dry Season TMDL Allocations to Existing Sources and Load Reductions Required to Achieve Hanalei Stream and Estuary Bacterial Standards (Table 15)

Enterococcus						
Wet Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.6E+12	7.0E+12	2.5E+12	35.0%
Hanalei River Estuary	4.9E+12	2.6E+11	5.1E+12	7.9E+12	2.8E+12	35.0%
Wet Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.6E+10	7.0E+12	7.0E+12	99.4%
Hanalei River Estuary	4.9E+10	2.6E+09	5.1E+10	7.9E+12	7.8E+12	99.4%
Dry Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.5E+12	7.0E+12	2.4E+12	35.0%
Hanalei River Estuary	4.8E+12	2.5E+11	5.1E+12	7.8E+12	2.7E+12	35.0%
Dry Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.5E+10	7.0E+12	6.9E+12	99.4%
Hanalei River Estuary	4.8E+10	2.5E+09	5.1E+10	7.8E+12	7.8E+12	99.4%

1. Introduction

Section 303(d) of the Clean Water Act (CWA) requires states to identify waterbodies (also referred to as receiving waters) that are not meeting their designated uses even though pollutant sources have implemented technology-based controls. In general, these waterbodies (i.e. receiving waters) are identified by comparing observed monitoring data to applicable water quality criteria (WQC) and waterbodies exceeding their WQC at a pre-defined frequency are considered impaired. These impaired waterbodies can be referred to as water quality limited segments (WQLSs) and are placed on the State's CWA §303(d) list. The CWA also requires states to establish a priority ranking of these WQLSs and to establish Total Maximum Daily Loads (TMDLs) for such waters. A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and in-stream water quality. It provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources and restore and protect the beneficial uses of the state's water resources (USEPA, 1991).

TMDLs represent a strategy for meeting WQC by allocating quantitative limits for point and nonpoint pollution sources. A TMDL is defined as the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background [40 CFR 130.2] such that the capacity of the waterbody to assimilate pollutant loading (i.e., the loading capacity) is not exceeded.

The TMDL process begins with the development of a technical analysis which includes the following components: (1) a **Problem Statement** describing which WQC are not being attained and which beneficial uses are impaired; (2) identification of **Numeric Targets** which will result in attainment of the WQC and protection of beneficial uses; (3) a **Source Analysis** to identify all of the point and nonpoint sources of the impairing pollutant in the watersheds and to estimate the current pollutant loading for each source; (4) a **Linkage Analysis** to calculate the Loading Capacity of the waterbodies for the pollutant; i.e., the maximum amount of the pollutant that may be discharged to the waterbodies without causing exceedances of WQC and impairment of beneficial uses; (5) a **Margin of Safety** (MOS) to account for uncertainties in the analyses; (6) the division and **Allocation of the TMDL** among each of the contributing sources in the watersheds, wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint and background sources; (7) a description of how **Seasonal Variation and Critical Conditions** are accounted for in the TMDL determination; and (8) a discussion of the **Public Participation** process.

The State of Hawai'i Department of Health (HIDOH) and the United States Environmental Protection Agency (USEPA) have coordinated a watershed assessment and modeling study to support the calculation of *enterococcus* and turbidity TMDLs for several waterbodies (or receiving waters) in the Hanalei Bay watershed, which are listed as impaired on the 2006 §303(d) list. These TMDLs are presented as load allocations for the nonpoint sources as well as the load reductions required (from existing loading levels) to achieve the TMDLs. Since turbidity is not a mass-based constituent and loads cannot be calculated, TSS TMDLs were used as a surrogate for turbidity

TMDLs (HIDOH, 2005; Oceanit Laboratories, Inc., et al., 2002), but turbidity WQC were incorporated into the TMDL calculation process for estuaries to ensure attainment of WQC.

Additional analyses were also performed to address waterbody-pollutant combinations that are not currently on the §303(d) list. Specifically, Informative TMDLs and Load Targets, and suggested load reductions, have been calculated in the Hanalei Bay watershed for nutrients and other pollutants where these targets may be helpful to achieve the TMDLs in the impaired waterbodies by addressing upstream segments or they may improve water quality in waterbodies showing exceedances, but not enough data are currently available to warrant placement on the §303(d) list, as described in Section 2. This document presents the results of the study and describes each TMDL component listed above, as it pertains to Hanalei Bay watershed receiving waters. Specifically, Section 3 describes the numeric WQC used for TMDL analyses, Section 4 compares the observed monitoring data to these WQC and analyzes water quality and hydrology monitoring data over the wet and dry seasons, Section 5 presents a source analysis, Section 6 describes the linkage analysis, Section 7 addresses the TMDL calculation methodology and results, and Section 9 discusses the public participation process. Section 8 fulfills EPA requirements for the phased TMDL approach and discusses an implementation framework that can be used to inform and support additional planning, monitoring, assessment, and polluted runoff control measures over time.

2. Problem Statement

The Hanalei River is one of Hawai'i's largest rivers and was designated as an American Heritage River in 1998. It drains into the Hanalei River Estuary approximately 3.5 river miles from its discharge to Hanalei Bay, which is also fed by the Waioli, Waipa, and Waikoko Stream estuaries. These watersheds (Hanalei, Waioli, Waipa, and Waikoko) are collectively referred to as the Hanalei Bay watershed. They support a variety of natural and anthropogenic activities, which are associated with different pollutants, including bacteria, sediment, and nutrients.

Enterococcus densities in the Hanalei River Estuary have exceeded the numeric WQC during at a sufficient frequency to place the waterbody on the §303(d) list (HIDOH, 2008). Although the *enterococcus* water quality standards are written in terms of density of indicator bacteria colonies, the actual risk to human health is caused by the potential presence of disease-causing pathogens, which can cause illness in recreational water users. When the risk to human health from pathogens in the water is so great that waterbodies or downstream beaches are posted with warnings, or closed, the quality and beneficial use of the water are impaired. At present, measuring pathogens directly is difficult and expensive, and for this reason, high concentrations of bacteria, which originate from the intestinal flora of warm-blooded animals, are used to indicate the presence of pathogens.

Sources of bacteria under all conditions vary widely and include natural sources such as feces from aquatic and terrestrial wildlife, and anthropogenic sources such as cesspools, septic tanks, illegal sewage disposal from boats along the coastline, trash, and pet waste. Once in the environment, bacteria can also regrow and multiply (Byappanahalli and Fujioka, 1998). Bacteria sources and their transport mechanisms to receiving waters are discussed in greater detail in Section 5.

The Hanalei River Estuary is also on the 2006 §303(d) list for turbidity, along with the Hanalei River, Waioli Stream Estuary, Waipa Stream Estuary, and Waikoko Stream Estuary, due to turbidity measurements in these waterbodies exceeding their associated wet and/or dry season numeric WQC (HIDOH, 2008). Turbidity measures the degree to which light is scattered and absorbed rather than transmitted in straight lines in a sample. It is caused by suspended matter (such as sediment, algae, bacteria, etc.) and provides an estimate of the opacity of the water. In addition to turbidity, total suspended solids (TSS) are often evaluated to characterize potential sources and quantify loadings of sediment. Sediment concentrations are associated with anthropogenic activities, including the introduction of feral livestock and agricultural and construction activities, as well as natural conditions, such as high precipitation and steep slopes. Sediment and turbidity sources in the Hanalei Bay watershed are further described in Section 5.

In addition to these listed impairments, several waterbodies also appear to be threatened by excessive nutrients; however, the monitoring datasets are not yet large enough to warrant placement on the §303(d) list. Nutrient loadings are generally lower in the freshwater segments than the estuarine areas and are associated with several watershed sources, which are discussed in Section 5. These sources include sediment, wildlife, fertilizers, and sewage. Nutrient TMDLs are not required by law because they are not currently on the §303(d) list; however, to inhibit further water quality degradation and to understand the reductions necessary to achieve applicable WQC, Informative TMDLs and Load Targets for nutrients have been calculated for the Hanalei Stream and Estuary, Waioli Stream and Estuary, Waipa Stream and Estuary, and Waikoko Stream and Estuary.

Various locations in Hanalei Bay are listed on the 2006 §303(d) list for exceeding the enterococcus and/or turbidity WQC (HIDOH, 2008). It is assumed that most of the pollutants in the Bay are transported via the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream; therefore, reducing the pollutant loads from these tributaries should improve the water quality in Hanalei Bay. Water quality within the Bay will become more thoroughly monitored and assessed in subsequent phases of TMDL development, when separate TMDLs will established for the Bay. Therefore, the TMDLs, Informative TMDLs, and Load Targets for streams and estuaries in the Hanalei Bay watershed are subject to refinement as the TMDL process continues.

2.1. Project Area Description

The Hanalei Bay watershed covers a 32.3 square-mile area draining to Hanalei Bay along the north shore of the Hawaiian island of Kaua'i. This drainage area includes the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream watersheds. Figure 1 illustrates the geographic location of each watershed and Table 1 identifies the area associated with each watershed. The Hanalei River watershed is the largest watershed in the Hanalei Bay system, making up 73.2% of the drainage area (23.6 square-miles). The Waioli Stream watershed is the second largest drainage area with nearly 5.5 square-miles, followed by the 2.5 square-mile Waipa Stream watershed and the 0.7 square-mile Waikoko Stream watershed.

The watershed originates atop the 5,240 foot Mount Wai'ale'ale, which receives an average of 450 inches of rainfall per year, while the coastal areas receive less than 100 inches of rainfall annually (University of Hawai'i, 2002). Figure 2 illustrates the incredibly wide rainfall distributions in the region. Much of the rainfall occurs during the wet season from November through April. Hanalei has a tropical climate with an average annual temperature in the mid-seventies and an average humidity in the low eighties (Weather Underground, 2006).

The rainfall patterns tend to follow the elevation contours in the region, with higher rainfall occurring in the higher elevations. Many of the higher elevation areas also have very steep slopes. This combination of steep slopes and high precipitation has a significant potential for erosion; thus contributing to the high turbidity values observed further downstream (see Section 5).

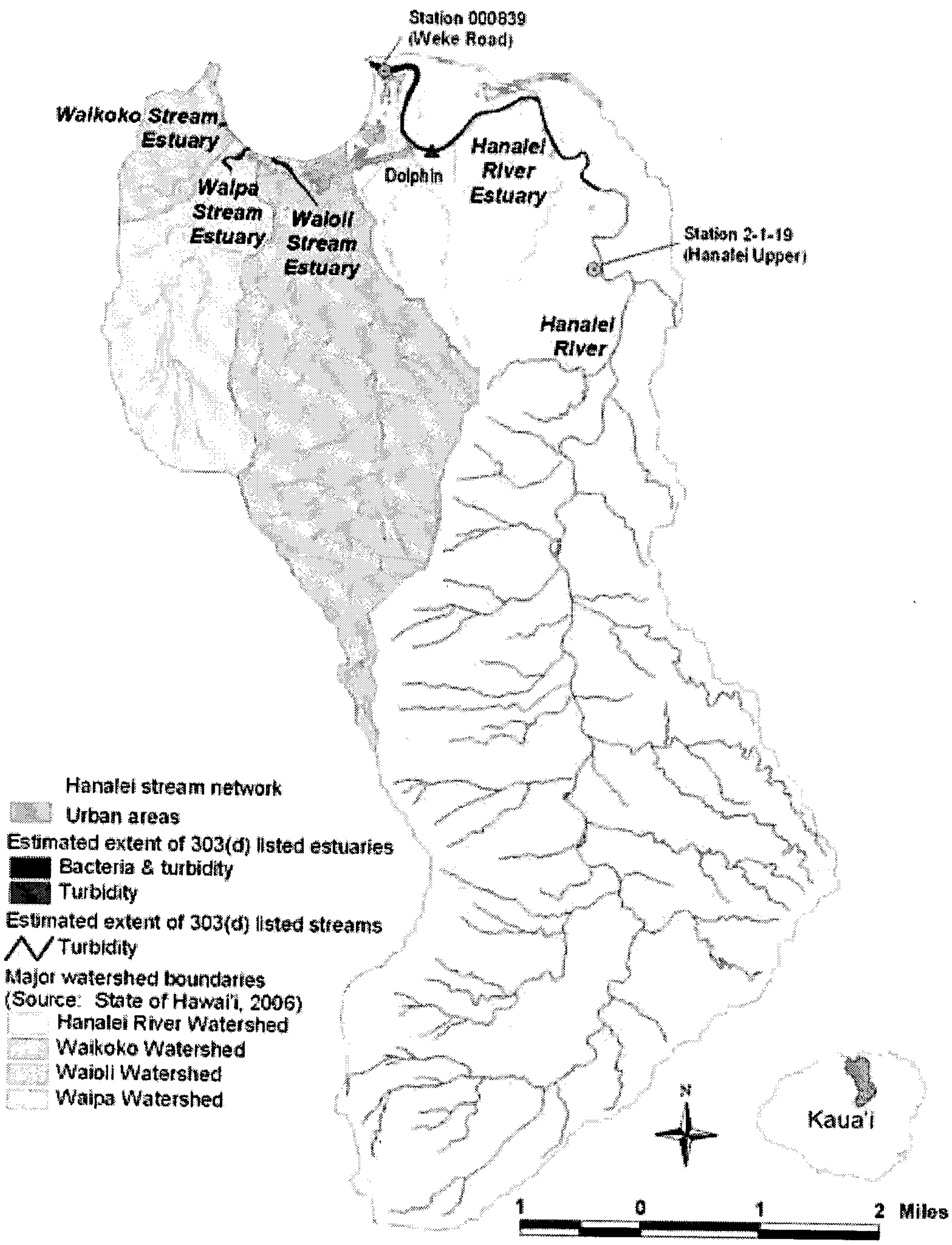


Figure 1. Hanalei Bay watershed

The Halelea Forest Reserve makes up a majority of the headwaters area. Agriculture, grassland, and urban areas are also drained before the Hanalei River and other tributaries discharge to the Hanalei Bay. In addition, the 16 mile Hanalei River passes through the Hanalei National Wildlife Refuge (NWR), which includes taro pondfields and several bird impoundments. The urban areas, which make up less than 1% of the land area, are primarily located in Hanalei town center along the Kuhio Highway (University of

Hawai'i, 2002). Figure 3 illustrates the percentage of total land area for each land cover category in the Hanalei Bay watershed (NOAA, 2000).

Table 1. Watershed Area (State of Hawai'i, 2006)

Watershed Name	Area (acres)	Area (square miles)	Percent of Total Area
Hanalei River	15,125.5	23.63	73.2%
Waioli Stream	3,482.7	5.44	16.9%
Waipa Stream	1,591.8	2.49	7.7%
Waikoko Stream	458.0	0.72	2.2%
Grand Total	*20,658.0*	*32.28*	*100%*

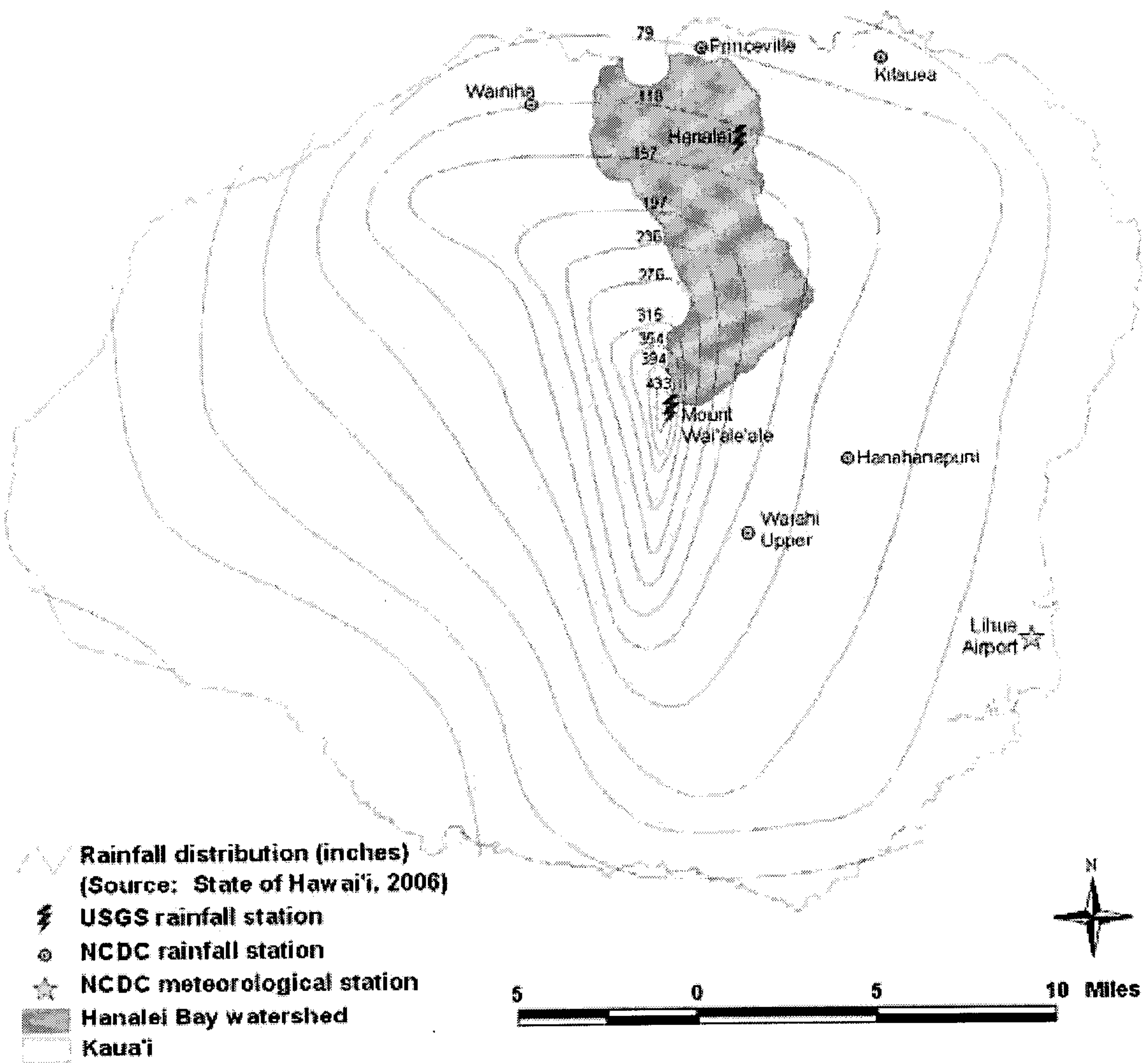


Figure 2. Kaua'i rainfall distribution

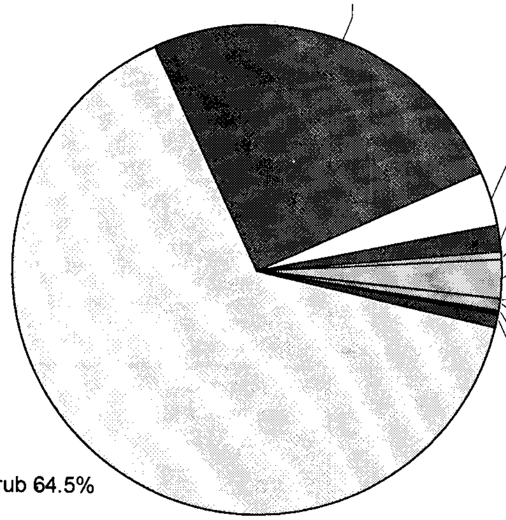


Figure 3. Hanalei Bay watershed land cover distribution (NOAA, 2000)

2.2. *Impairment Overview*

The waterbodies included in this project were listed as impaired due to non-attainment of the indicator bacteria and/or turbidity WQC. For streams, separate wet and dry season (defined as November to April and May to October, respectively) WQC are applicable, while seasonal variation is not considered in the estuary and the WQC are applicable throughout the year. The §303(d) listings, which were determined from comparing monitoring data with the appropriate WQC, are identified in Figure 1 and Table 2. This table also identifies the watershed that drains or contributes to the impaired waterbody, the basis for listing, and geographic scope of the listing, while Figure 1 illustrates the locations of the water quality monitoring stations represented in the station number column and the extent of the waterbodies (including the location of the Dolphin Restaurant [represented by a blue triangle] along the Hanalei River Estuary, which is referenced in the turbidity listing). For the Hanalei Stream and Waipa Stream turbidity listings, only the dry season (May to October) stream WQC was exceeded, while all of the estuary listings are applicable year-round (Table 2).

The current TMDL process reflects a consolidation of listings for inland waterbodies rather than individual stations within a waterbody (i.e. TMDLs address entire streams and/or entire estuaries). Specifically, three listings in the Hanalei River Estuary were consolidated into two waterbody-pollutant combinations. The Hanalei River Estuary turbidity impairments associated with two geographic areas [upstream of Dolphin and Weke Road station (Figure 1)] were grouped to address the entire estuary. The Hanalei River Estuary is also listed for *enterococcus* impairments. This consolidation process ultimately resulted in TMDL development for eight (8) waterbody-pollutant combinations in the Hanalei Bay watershed. These waterbody-pollutant combinations are identified below in
Table 3.

Table 2. Water Quality Limited Segments Addressed in This Analysis (HIDOH, 2008)

Watershed	Scope of Assessment	Pollutant	Basis for Listing	Geocode ID	Standard*
Waipa	Waipa Stream – Entire Network	turbidity	numeric assessment	2-1-17	dry season
Hanalei River	Hanalei Stream – Entire Network	turbidity *enterococcus*	numeric assessment	2-1-19	dry season
Hanalei River	Hanalei Bay upstream of Dolphin (Estuary)	turbidity	numeric assessment	HIW00160	year round
Hanalei River	Hanalei River (Estuary)	turbidity *enterococcus*	numeric assessment	HI385259	year round
Waikoko	Waikoko Estuary	turbidity	numeric assessment	HIW00162	year round
Waioli	Waioli Stream Estuary	turbidity	numeric assessment	HIW00163	year round
Waipa	Waipa Stream Estuary	turbidity	numeric assessment	HIW00164	year round

Table 3. Waterbody-Pollutant Combinations Addressed by the Hanalei Bay Watershed TMDLs

Listed Waterbody	Pollutant	Standard*	Watershed
Hanalei Stream	turbidity	dry season	Hanalei River
Hanalei Stream	*enterococcus*	year round	Hanalei River
Hanalei River Estuary	turbidity	year round	Hanalei River
Hanalei River Estuary	*enterococcus*	year round	Hanalei River
Waioli Stream Estuary	turbidity	year round	Waioli
Waipa Stream	turbidity	dry season	Waipa
Waipa Stream Estuary	turbidity	year round	Waipa
Waikoko Stream Estuary	turbidity	year round	Waikoko

*Streams have wet and dry season turbidity standards (November to April and May to October, respectively; however, estuary standards are applied throughout the year (see Table 5 and Table 6 below). *Enterococcus* standards for estuary and stream are applied throughout the year.

As described previously, various locations in Hanalei Bay are listed on the 2006 §303(d) list for exceeding the enterococcus and/or turbidity WQC (HIDOH, 2008). Separate TMDLs for Hanalei Bay have not been developed at this time, but will be considered in the next phase of TMDL development.

In addition to the waterbody-pollutant combinations identified in Table 3, Informative TMDLs and Load Targets were also calculated for several other combinations (Table 4). These calculations serve several purposes. In some instances achieving them will contribute to meeting WQC in the §303(d) listed waterbodies and can be used as an implementation tool (for example, Informative TMDLs for nutrients contribute to the achievement of the turbidity WQC). They are also helpful to reduce pollutant loads in other receiving waters where water quality monitoring and assessment data suggest that reductions may be required, although current datasets are not yet robust enough to warrant placement on the §303(d) list (for example, several waterbodies in the Hanalei Bay watershed appear to be threatened by nutrients, as described in Section 4), and to provide a quantitative measure against which the success of the State antidegradation policy can be evaluated. "Load Targets" are calculated only for ammonia concentrations in streams, based on the assumption that achieving the estuary ammonia criteria in streams (where it is not an explicit part of the standards, otherwise these would be Informative TMDLs) would be protective of stream nitrogen and turbidity standards.

Table 4. Waterbody-Pollutant Combinations Addressed with Informative TMDLs and Load Targets

Waterbody	Pollutant	Watershed
INFORMATIVE TMDLs		
Hanalei Stream	nitrite plus nitrate total nitrogen total phosphorous	Hanalei River
Hanalei River Estuary	ammonia nitrite plus nitrate total nitrogen total phosphorous	Hanalei River
Waioli Stream	*enterococcus* nitrite plus nitrate total nitrogen total phosphorous total suspended solids turbidity	Waioli
Waioli Stream Estuary	*enterococcus* ammonia nitrite plus nitrate total nitrogen total phosphorous	Waioli
Waipa Stream	*enterococcus* nitrite plus nitrate total nitrogen total phosphorous total suspended solids	Waipa
Waipa Stream Estuary	*enterococcus* ammonia nitrite plus nitrate total nitrogen total phosphorous	Waipa
Waikoko Stream	*enterococcus* nitrite plus nitrate total nitrogen total phosphorous total suspended solids turbidity	Waikoko
Waikoko Stream Estuary	*enterococcus* ammonia nitrite plus nitrate total nitrogen total phosphorous	Waikoko
LOAD TARGETS		
Hanalei Stream	ammonia	Hanalei River
Waioli Stream	ammonia	Waioli
Waipa Stream	ammonia	Waipa
Waikoko Stream	ammonia	Waikoko

3. Numeric Target Selection

When calculating TMDLs, numeric targets are established to meet WQC and subsequently ensure the protection of beneficial uses. Beneficial uses in Hanalei inland receiving waters are Class 1 or Class 2, depending upon underlying land use designations and regulations, as described below and shown in Figure 4:

Class 1 It is the objective of Class 1 waters that these waters remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. To the extent possible, the wilderness character of these areas shall be protected. Waste discharge into these waters is prohibited. Any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination in Class 1 waters is prohibited (HIDOH, 2004).

Class 1.a. The uses to be protected in Class 1.a waters are scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other nondegrading uses which are compatible with the protection of the ecosystems associated with waters of this class (HIDOH, 2004).

Class 1.b. The uses to be protected in Class 1.b waters are domestic water supplies, food processing, protection of native breeding stock, the support and propagation of aquatic life, baseline references from which human-caused changes can be measured, scientific and educational purposes, compatible recreation, and aesthetic enjoyment. Public access to these waters may be restricted to protect drinking water supplies (HIDOH, 2004). These restricted areas are protective subzones within the conservation district. The objective of a protective subzone is to protect valuable resources in designated areas such as restricted watersheds, marine, plant, and wildlife sanctuaries, and sites, and other designated unique areas, as described in Chapter 13-5 of the Hawai'i Administrative Rules (DLNR, 1994).

Class 2 The objective of Class 2 waters is to protect their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. The uses to be protected in this class of waters are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class. No new treated sewage discharges shall be permitted within estuaries (HIDOH, 2004).

Portions of Hanalei Stream System that run through the National Wildlife Refuge (lower stream reach and upper estuary shown in yellow on Figure 4 below) and through recently-designated critical habitat areas (shown in white with magenta borders on Figure 4 below) for the federally-endangered Newcomb's snail (*Erinna newcombi*) are Class 1.a. Hanalei Stream headwaters, and a portion of upper reach tributaries, are Class 1.b., as are the upper reaches of Waioli Stream and Waipa Stream (areas shown with red hatching on Figure 4 below). All remaining waters, including a large portion of Hanalei Stream upper reaches; the lower reach of Hanalei Estuary; the lower reaches of Waioli Stream and Waipa Stream and their estuaries; and the entire Waikoko Stream System (stream and estuary) are Class 2 (other areas in Figure 4 below).

Existing uses of these waterbodies have not been fully confirmed, however the only designated uses that may not be presently occurring in the respective segments are Class 1.b. domestic water supplies and food processing and Class 2 shipping and industrial water supplies. Many Class 1 uses currently exist in Class 2 waters, and perhaps vice-versa, such as scientific, educational, biological (natives), and aesthetic use of Class 2 waters and agricultural and commercial (navigation) use of Class 1 waters. Support of traditional and customary native Hawaiian beliefs, values, and practices is an ongoing use of all waters, along with many of the other "reasonable and beneficial uses" and instream uses protected under the State Water Code (Hawaii Revised Statutes Chapter 174C).

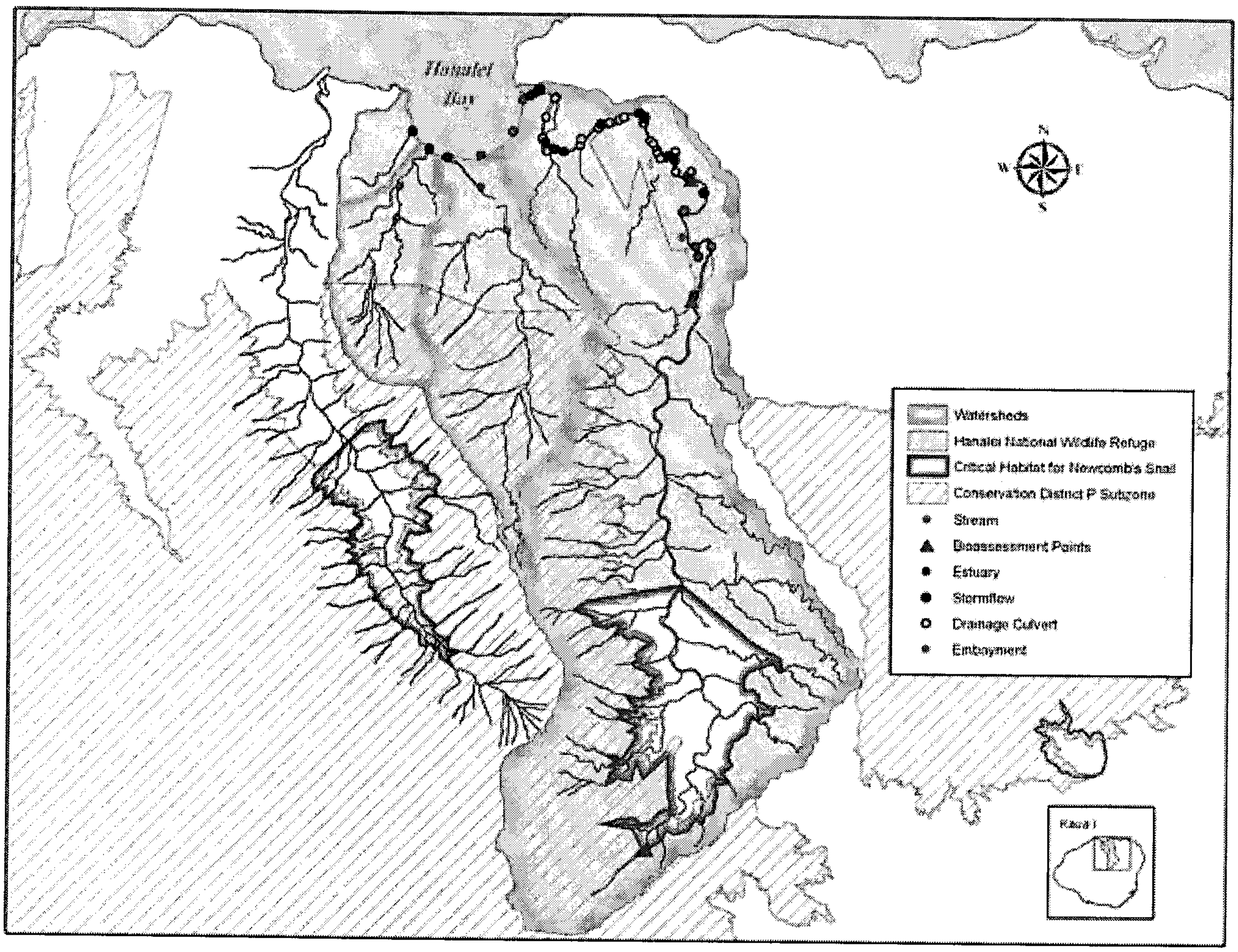


Figure 4. Factors affecting waterbody Class within the Hanalei Bay watershed

TMDLs were calculated for each impaired waterbody and for each pollutant listed in Table 3 using the WQC identified in the Hawai'i Administrative Rules (HAR) Title 11, Department of Health Chapter 54, Water Quality Standards, which were approved on August 31, 2004 (HIDOH, 2004). Load targets for the waterbody-pollutant combinations listed in Table 4 were developed using criteria identified in the same source. The numeric targets selected in the TMDL and load reduction analyses depended on whether the impaired waterbody was a stream or estuary. In addition, different dry and wet season numeric targets were used for the streams, consistent with the HAR (HIDOH, 2004). The HAR presents four different types of "not to exceed" (NTE) numeric criteria, which are described below:

Geometric mean	For the nutrient and sediment parameters, the geometric mean of all samples should not exceed this value. For *enterococcus*, the geometric mean is calculated on not less than five samples spaced to cover a period between 25 and 30 days. However, if five *enterococcus* samples are not collected within a 30 day period, the geometric mean is calculated on the samples taken within the 30-day period.
Not to exceed more than 10% of the time	For the nutrient and sediment parameters, no more than 10% of all time-averaged samples should exceed this value (does not apply to *enterococcus*).
Not to exceed more than 2% of the time	For the nutrient and sediment parameters, no more than 2% of all time-averaged samples should exceed this value (does not apply to *enterococcus*).
Single sample maximum	For *enterococcus* only, no single sample shall exceed this value (does not apply to the nutrient and sediment parameters).

The numeric targets for the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream Estuaries are presented in Table 5, while the targets for the Hanalei River, which are separated by season, are presented in Table 6. These tables include the numeric targets for parameters associated with the TMDL calculations (for waterbody-pollutant combinations identified in
Table 3 and 4) as well as load targets (for waterbody-pollutant combinations identified in 5). As indicated previously, TSS was used as a surrogate for turbidity during TMDL and load target analyses because turbidity is not mass-based and therefore cannot be used to calculate loads (HIDOH, 2005; Oceanit Laboratories, Inc., et al., 2002). However, stream and estuary turbidity WQC were incorporated into the TMDL analyses to ensure attainment of WQC in the estuaries (where no TSS WQC exists). Correlative analyses confirm the relationship between TSS and turbidity (R^2 value of 0.7175, as described below in Section 4.3.2.3 and illustrated in Figure 15), further justifying this approach.

The numeric targets used for TMDL and load target development are based on the WQC presented in the HAR (HIDOH, 2004). These WQC are limits or levels that were established for the protection of designated uses of the waters of the state. Therefore, attainment of these WQC will result in restoration and protection of the designated uses described above. Bacteria WQC provide an example of a fairly direct relationship between WQC attainment and use attainment. Specifically, achieving the *enterococcus* WQC results in the attainment of the recreational beneficial use, based on assumption that that the WQC represents an acceptable threshold of public health risk for full-body contact. For other designated uses, the relationship between use attainment and the attainment of one or more WQC is generally less well-defined.

Table 5. Estuary Numeric Targets

Parameter (units)	Application in Hanalei Bay watershed	NTE geometric mean	NTE more than 10% of the time	NTE more than 2% of the time
Total Nitrogen (milligrams per liter [mg/L])	Informative TMDL calculation [a]	0.200	0.350	0.500
Ammonia Nitrogen (mg/L)	Informative TMDL[b] and Load Target[c] calculation	0.006	0.010	0.020
Nitrite + Nitrate Nitrogen (mg/L)	Informative TMDL calculation[d]	0.008	0.025	0.035
Total Phosphorous (mg/L)	Informative TMDL calculation [a]	0.025	0.050	0.075
Turbidity (Nephelometric Turbidity Units [NTU])	TMDL calculation[e]	1.5	3	5
Parameter	**Application in Hanalei Bay watershed**	**NTE geometric mean[c]**		**Single sample maximum**
Enterococcus (cfu/100mL)	TMDL and Informative TMDL calculation	33		89

[a] Also protective of turbidity standards
[b]Also protective of Total Nitrogen, Nitrate+Nitrogen, and turbidity standards
[c] Also protective of Total Nitrogen, Nitrate+Nitrogen, and turbidity standards in streams when applied to stream concentrations and loadings
[d]Also protective of Total Nitrogen and turbidity standards
[c]Numeric target for TSS loading based on statistical relationship with TSS concentrations
[e] Geometric mean based on a minimum of five samples spaced between 25 and 30 days

Table 6. Stream Numeric Targets

Parameter	Season[a]	Application in Hanalei Bay watershed	NTE geometric mean	NTE more than 10% of the time	NTE more than 2% of the time
Total Nitrogen (mg/L)	Wet	Informative TMDL calculation[b]	0.250	0.520	0.800
	Dry		0.180	0.380	0.600
Nitrite + Nitrate Nitrogen (mg/L)	Wet	Informative TMDL calculation[c]	0.070	0.180	0.300
	Dry		0.030	0.090	0.170
Total Phosphorous (mg/L)	Wet	Informative TMDL calculation[b]	0.050	0.100	0.150
	Dry		0.030	0.060	0.080
Total Suspended Solids (mg/L)	Wet	TMDL and Informative TMDL calculation[d]	20	50	80
	Dry		10	30	55
Turbidity (NTU)	Wet	TMDL and Informative TMDL calculation	5	15	25
	Dry		2	5.5	10

Parameter	Application in Hanalei Bay watershed	NTE geometric mean[e]	Single sample maximum
Enterococcus (cfu/100mL)	TMDL and Informative TMDL calculation	33	89

[a] Wet season = November 1 through April 30; Dry season = May 1 through October 31
[b] Also protective of turbidity standards
[c] Also protective of Total Nitrogen and turbidity standards
[d] Used as numeric target for turbidity endpoint in estuaries based on statistical relationship with turbidity values. Also protective of Total Nitrogen, Total Phosphorous, and enterococcus standards in streams and estuaries when applied to stream and estuary concentrations and loadings.
[e] Geometric mean based on a minimum of five samples spaced between 25 and 30 days

Stream biological assessment scores provide an evaluative measure of ecosystem health that can be used to develop numeric targets for stream environmental improvements. DOH's assessment methodology employs a holistic approach that evaluates the entire watershed as an extended ecological unit. Instead of simply evaluating specific points along the stream to determine species composition and abundance, we consider multiple lines of evidence to diagnose the overall health of the entire system. These lines of evidence include the habitat available for various species, both native and introduced; riparian zone integrity and composition; evidence of erosion, scour, and deposition; bottom types and substrate composition; and water chemistry, as well as information obtained from previous studies, water and land use records, and land cover classifications.

The Hawaii Stream Bioassessment Protocol (HSBP), version 3.01 (Kido, 2002), and the Hawaii Stream Visual Assessment Protocol (HSVAP) (NRCS, 2001) were conducted between August 29, 2006 and September 1, 2006 at 4 sites in the Hanalei Stream watershed. The assessments were conducted on relatively sunny days with a few light rain showers. Figure 5 shows the Hanalei HSBP results in relation to HSBP scores for three high-quality reference streams (including nearby Hanakapiai, Kauai).

Both upper sites are located in relatively intact native forest with a small percentage of invasive plant species cover. The upper Mai'a site contains invasive Australian Fern and Clidemia as the dominant invasive, while the upper LZ-15 site contains Yellow Guava as the dominant invasive species. No stream channel alterations were present, and no fine sediment was observed, or indicated by turbidity, bottom type and bank stability scores. The investigation was conducted along a 100 meter length of stream channel in each location.

The Mai'a site is high gradient >10% slope, 2 to 5 meters wide, and located above a significant waterfall. The water temperature was 17.6° Centigrade. The only aquatic species noted at this site was 'Opae Kala'ole (Atyoida bisulcata). Additional species noted included a significant number of aquatic flies, and adult native dragonfly and damselflies were seen throughout the sampling site.

The LZ-15 site is medium gradient, >5% slope, 4 to 10 meters wide, with no significant migration barriers noted downstream. The water temperature was 20.7° Centigrade. This site contained native fish of species 'O'opu Nakea (Awaous guamensis) and 'O'opu Alamo'o (Lentipes concolor), but in very small numbers with a total of only 5 fish found in 100 meters of reach. 'Opae Kala'ole were also found in low numbers within this reach. Bullfrog juveniles (Rata catesbeiana) were the only invasive aquatic species identified. Again, native dragonfly and damselfly adults were seen along the stream corridor.

Overall, the upper sites are in good condition. The HSBP scores for the Mai'a site were Habitat - 95%, Biotic Integrity – 69%. The HSVAP score was 1.8 of 2.0. The HSBP scores for the LZ-15 site were Habitat – 96%, Biotic Integrity – 71%. The HSVAP score was 1.75 of 2.0. These scores reflect excellent supporting habitat with a borderline, moderately impaired biotic component, apparently due to limited recruitment, biomass, and diversity of native species.

The two lower elevation sites are significantly different from the upper sites. Invasive forest of Hau (Hibiscus tiliaceus), Rose apple (Syzygium jambos), Bamboo, Banyan (Ficus microcarpa), ginger and Albizia (Albizia lebbeck) dominates the riparian zone. The great width of the stream required that the reaches assessed be 400 and 600 meters long.

The Middle site, located at the USGS stream gauge, is low gradient, < 4% slope, and very wide. The width ranged from 25 to 37 meters and the temperature was 23.6° Centigrade. The bottom substrate was dominated by cobble and rock, with silt and clay deposits in the pools. Banks were severely eroded with undercuts evident. This degraded habitat offered refuge for several species of invasive aquatic species including Tahitian prawns (Macrobrachium lar), Smallmouth bass (Micropterus dolomieu) and swordtails (Xiphophorus helleri). The native species observed within this reach included 'O'opu nakea (Awaous guamensis), 'O'opu nopili (Sicyopterus stimpsoni), 'O'opu 'akupa (Eleotris sandwicensis), 'Aholehole (Kuhlia sandwicensis) and 'O'opu naniha (Stenogobius hawaiiensis). No native crustaceans or snails were observed.

The Lower site located near the Ducks Unlimited property (but above the estuary) was very murky and had significant erosion problems along the banks. However, the reach also had several riffle habitat areas that provided good habitat for native species. Severe undercutting was observed on the right bank within an overhanging Hau grove. This degraded habitat offered refuge for several species of invasive aquatic species including

Tahitian prawns (Macrobrachium lar), Smallmouth bass (Micropterus dolomieu) and swordtails (Xiphophorus helleri). The native species observed within this reach included ‘O’opu nakea (Awaous guamensis), ‘O’opu ‘akupa (Eleotris sandwicensis), ‘Aholehole (Kuhlia sandwicensis) and ‘O’opu naniha (Stenogobius hawaiiensis). No native crustaceans or snails were observed.

The HSBP scores for the Middle site were Habitat - 81%, Biotic Integrity – 53 %. The HSVAP score was 1.3 of 2.0. The HSBP scores for the Lower site were Habitat – 56%, Biotic Integrity – 53%. The HSVAP score was 1.2 of 2.0.

Previous investigations by various researchers indicate that a significant population of introduced species, including several predacious species, has been established in Hanalei. Results from our assessments indicate that a relatively healthy aquatic community was present in the watershed. Overall species composition was favorable, but habitat was degraded in the lower sites by bank erosion and riparian degradation.

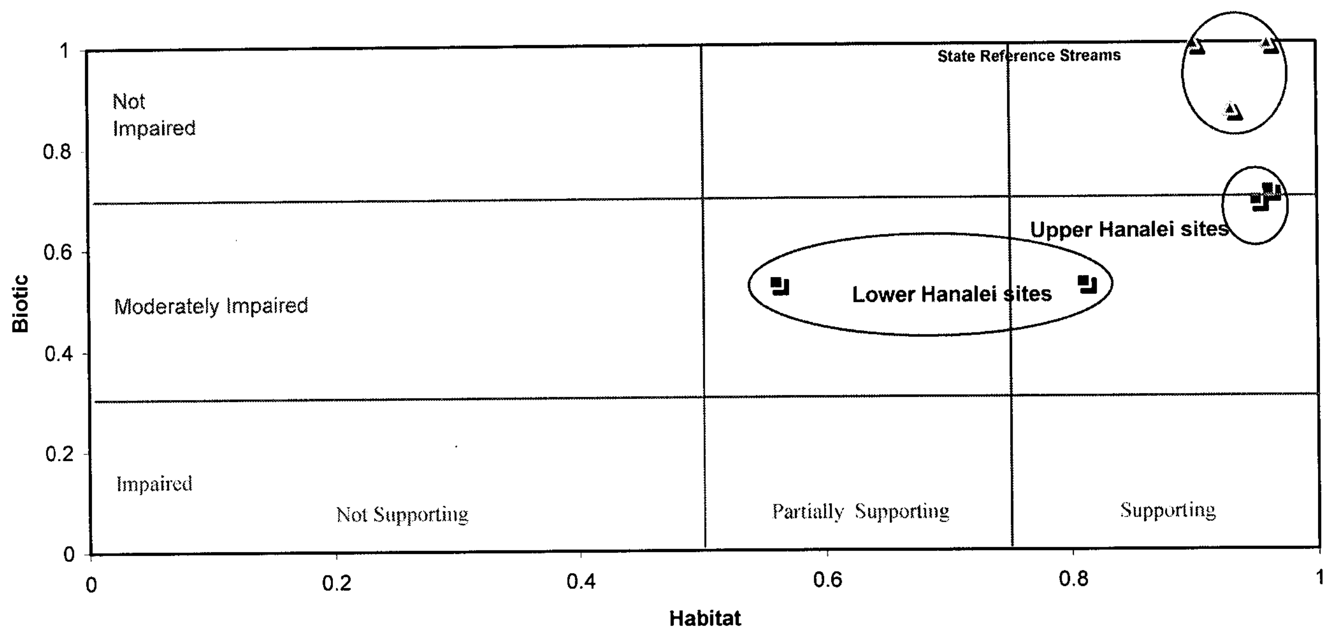


Figure 5. Stream Bioassessment Results, Hanalei Stream

4. Data Inventory and Analysis

Data from numerous sources were used to represent the watersheds and estuaries, characterize their water quality conditions, identify potential sources associated with *enterococcus*, sediment, and nutrients, and support the calculation of TMDLs and load targets. Some of these data were used to configure watershed and receiving water models, while other data and information were used in data analyses to provide an understanding of the conditions that result in water quality impairments. The remainder of this section provides an inventory of data, a summary of hydrologic conditions in the watershed, and analyses to review the impairments and threatened segments.

4.1. Data Inventory

The categories of data used in developing these TMDLs include physiographic data that describe the physical conditions of the watershed and environmental monitoring data that identify past and current conditions and support the identification of potential pollutant sources. Table 7 presents the various data types and data sources used in the development of these TMDLs. The following sections describe the key data sets used for TMDL development and analyses: water quality, hydrologic, meteorological, and watershed characteristic data.

Table 7. Inventory of Data and Information

Data Type	Data Source(s)
Environmental Monitoring Data	
Water quality monitoring data	HIDOH (HIDOH, 2006); Hanalei Watershed Hui (Berg, 2006); United States Geological Survey (USGS; USGS, 2006)
Streamflow data	USGS (USGS, 2006); HIDOH (HIDOH, 2006); Hanalei Watershed Hui (Berg, 2006)
Meteorological data	USGS (USGS, 2006); National Oceanic and Atmospheric Administration - National Climatic Data Center (NOAA-NCDC, 2006)
Physiographic Data	
Stream network	Hawai'i Statewide GIS Program (State of Hawai'i, 2006)
Land cover	NOAA Coastal Change Analysis Program (C-CAP) (NOAA, 2000)
Soils	USDA State Soil Geographic Data Base (STATSGO) (USDA, 2006)
Watershed boundaries	Hawai'i Statewide GIS Program (State of Hawai'i, 2006)
Topographic and digital elevation models (DEMs)	United States Geological Survey (USGS, 2005); Hawai'i Statewide GIS Program (State of Hawai'i, 2006)

4.1.1. Water Quality Data

Water quality monitoring data for bacteria, sediment, and nutrients in the Hanalei Bay watershed were obtained from the HIDOH Clean Water Branch (HIDOH, 2006), the Hanalei Watershed Hui (Hui) (Berg, 2006), and the United States Geological Survey

(USGS, 2006). These data were collected at 62 stations located within or tributary to impaired or threatened waterbodies. Figure 6. illustrates the spatial distribution of water quality monitoring stations by location type. These data, which were collected between January 1995 and May 2006, were well distributed among the wet and dry seasons, as indicated in Table 8; however, the number of samples collected at each station varied significantly. The number of samples collected under baseflow and stormflow conditions is also presented in Table 8. Days were classified as baseflow or stormflow by obtaining average daily flow values at the USGS gage for January 1995 through May 2006 (which overlaps with the water quality data record). The days corresponding to the highest ten percent of flows were assigned to the stormflow category and then the number of samples falling under the stormflow and baseflow categories was tabulated. With the exception of the suspended sediment concentration (SSC) data collected by USGS, a vast majority of the records summarized in Table 8 were grab samples. The SSC data and a few samples collected in March 2006 were collected using automatic samplers. Water quality data were analyzed to evaluate seasonal distribution, waterbody type (i.e. stream, estuary, etc.), and relationships between parameters. The results of these analyses are presented in Section 4.3. Some of these data were also used for watershed and receiving water calibration and validation, which are described in the Modeling Report, Appendix B.

4.1.2. Hydrologic Data

Several sources of flow data were available for the Hanalei Bay watershed, including both continuous and discrete measurements. The continuous flow measurements include data collected at the USGS gage on the Hanalei River (station 16103000). Continuous flow data have been obtained for this station from May 1, 2001 – May 31, 2006 (USGS, 2006). Discrete flow measurements were collected between November 2001 and September 2005 as part of the water quality sampling protocol during several events (Berg, 2006; HIDOH, 2006).

While there are no National Pollutant Discharge Elimination System (NPDES) dischargers that are major point sources of flow or pollutants in the Hanalei Bay watershed, there are flow diversions to wetland impoundments and taro pondfields at the Hanalei National Wildlife Refuge (NWR). These diversions are estimated to have an average constant withdrawal from the irrigation ditch system of 34 cubic feet per second (cfs) (USFWS, 2005). It was estimated that an average 65 percent (22.1 cfs) of the inflows return to the Hanalei River because consumptive use is lower than the inflow requirements (USFWS, 2005).

These flow measurements were incorporated into the watershed and receiving water models and were utilized for model calibration and validation, as described in the Modeling Report, Appendix B. The continuous flow measurements were also analyzed to summarize the Hanalei River flow ranges observed during wet and dry seasons, as described in Section 4.2.

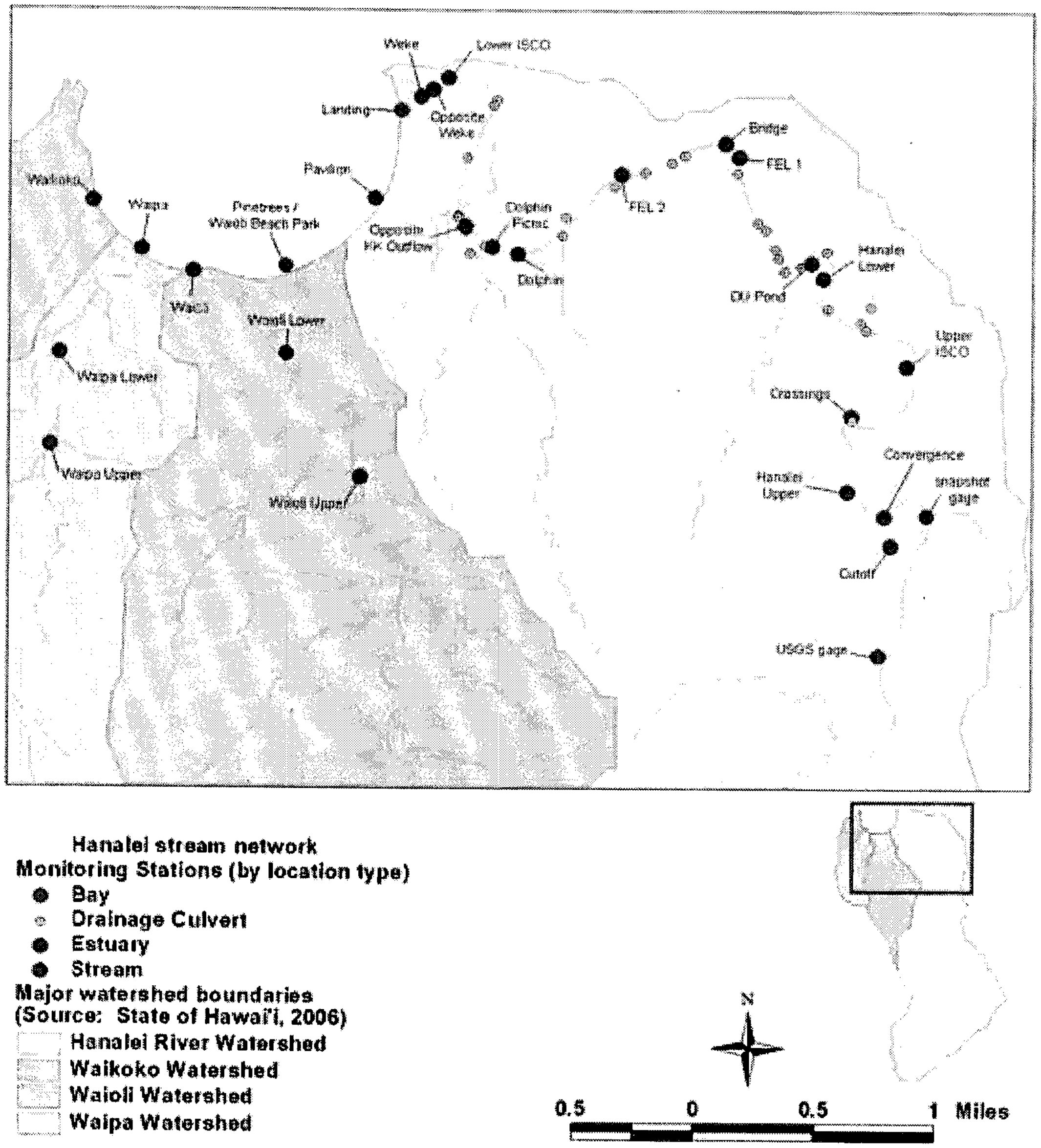


Figure 6. Water quality monitoring stations by location type

Table 8. Seasonal and Flow Regime Distribution of Water Quality Data

Parameter (units)	Number of Samples			
	Dry Season	Wet Season	Baseflow	Stormflow
Bacteria				
Enterococci (#/100mL)	2351	2062	3914	499
Sediment				
Turbidity (NTU)	1303	1519	2460	362
TSS (mg/L)	88	104	148	44
Suspended sediment (mg/L)	375	439	690	124
Nutrients				
Ammonia (mg/L)	88	99	145	42
Nitrite plus Nitrate (mg/L)	90	99	147	42
Total Nitrogen (mg/L)	89	98	146	41
Total Phosphorous (mg/L)	89	98	146	41

4.1.3. Meteorological Data

The Hanalei Bay watershed has an incredibly wide distribution of rainfall, as depicted in Figure 2. The headwaters are near Mount Wai'ale'ale, which receives over 450 inches of rainfall annually and is one of the rainiest places on earth, and the coastal areas near the mouth of the watersheds (less than 10 miles from Mount Wai'ale'ale) receive less than 100 inches of rain per year. Because of this extreme variability and its impact on stream flows, it was important to represent the rainfall distribution in the watershed using appropriate rainfall gages.

United States Geological Survey (USGS) and National Oceanic and Atmospheric Administration-National Climatic Data Center (NOAA-NCDC) precipitation data were reviewed based on geographic location, rainfall distribution, period of record, and missing data to determine the most appropriate meteorological stations (USGS, 2006; NOAA-NCDC, 2006). Hourly rainfall data were obtained from two USGS rainfall stations located near the Hanalei Bay watershed (Figure 2): Mount Wai'ale'ale and Hanalei. Data for these stations were obtained from USGS for May 1, 2001 through May 31, 2006.

In addition, hourly potential evapotranspiration values were calculated using data from the Lihue Airport NCDC station. Solar radiation, wind speed, cloud cover, air temperature, and dew point data were also obtained for the watershed modeling, which were supplemented by relative humidity, wind direction, and sea level pressure from Lihue Airport for the receiving water model.

4.1.4. Watershed Characteristic Data

Various types of watershed characteristic data were incorporated into the modeling study of the Hanalei Bay watershed. These data include, but are not limited to, land cover, soils, and elevation. The National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover image from a remote sensing study in 2000 (NOAA, 2000) was used to represent land cover in the watershed. There were originally thirteen C-CAP land cover categories present in the Hanalei Bay watershed. To simplify model parameterization, land categories that share hydrologic or pollutant loading characteristics were grouped, resulting in ten land cover categories for modeling, which are described and illustrated in the Modeling Report, Appendix B.

Soils data were obtained from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) database (USDA, 2006), digital elevation model (DEM) data were obtained from the USGS (USGS, 2005), and elevation contours were obtained from the Hawai'i Statewide GIS Program (State of Hawai'i, 2006). Because steep slopes have the potential to contribute larger amounts of sediment than gentler slopes, areas with steep slopes were identified using the DEM. The soils in these areas were identified as having high erosive potential in the modeling study.

4.2. Long-Term Hydrologic Analysis

Twenty years of average daily flows at the USGS gage Hanalei River station (station 16103000) were evaluated to characterize temporal patterns over a range of hydrologic conditions. Specifically, monthly minimum, maximum, mean, and median flows were calculated based on daily measurements for June 1987 through May 2006. These summary statistics are presented in Table 9 and illustrated in Figure 7.7.

Table 9. Monthly Flow Statistics – June 1987 through May 2006

Month	Flow for June 1987 – May 2006 (cfs)				
	Number of Daily Measurements	Minimum	Maximum	Mean	Median
January	589	66	4,770	257	121
February	537	66	4,380	243	125
March	589	58	4,880	272	133
April	570	56	2,660	246	180
May	589	60	1,750	186	129
June	570	57	901	165	121
July	589	54	3,040	192	138
August	589	70	1,800	169	130
September	570	60	3,210	206	131
October	589	71	2,040	206	136
November	570	70	7,100	299	167
December	589	72	4,550	263	158

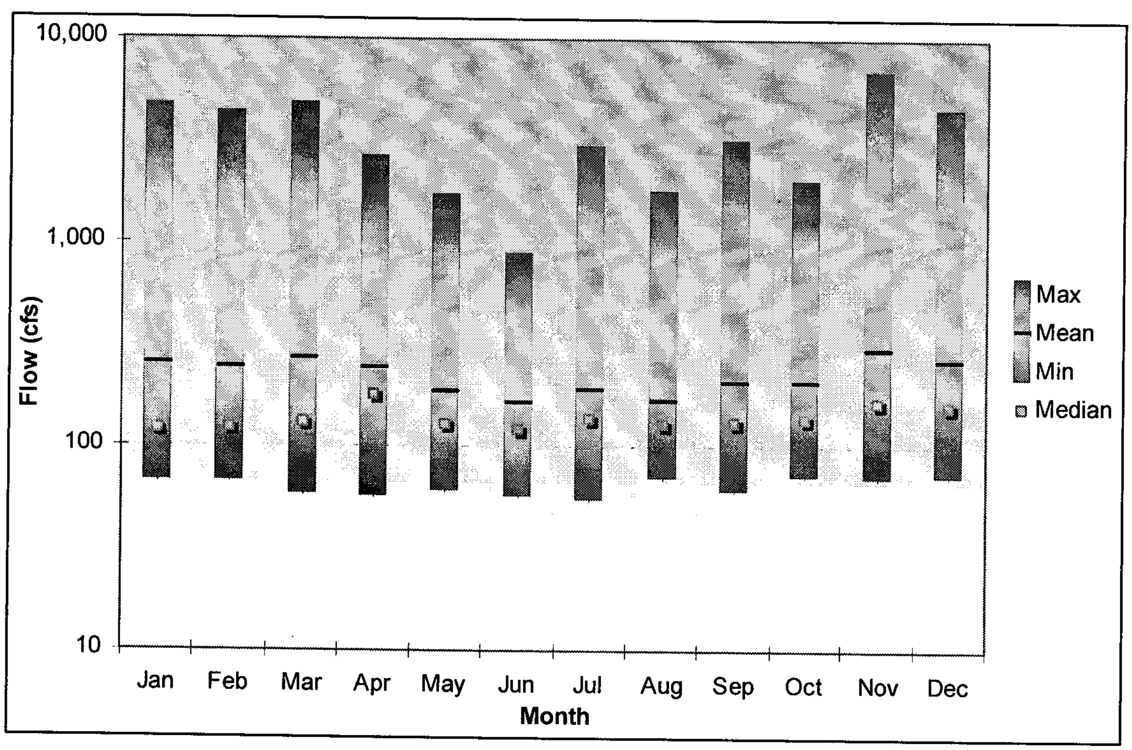


Figure 7. Monthly Flow Values – June 1987 through May 2006

The HAR defines the wet season in Hawai'i as November 1 through April 30 and the dry season as May 1 through October 31 (HIDOH, 2004). The above table and figure show that November through April have higher mean flows than May through October, which is consistent with the HAR definitions of wet and dry seasons. The minimum flow for each month is similar (range of 54 to 72 cfs) and, as expected, the maximum flows exhibit much wider variability over the 20 year period. In general, November through April have higher maximum flows than the other months, except for July and September, which show higher maximum values than in April. These data indicate that although November through April are the wettest months of the year, large storms also occur during the dry season, which may result in significant loads to the watershed.

4.3. Water Quality Data Analyses

Bacteria, sediment, and nutrients data collected from stream, estuary, and bay segments were analyzed to provide guidance for the source assessment. These data include wet and dry season sampling conducted by the Hui (Berg, 2006) and HIDOH (HIDOH, 2006) as well as stormwater monitoring. The primary stormwater monitoring was conducted as a collaborative effort between HIDOH, the Hui, and Tetra Tech. This monitoring resulted in bacteria, sediment, and/or nutrients data collected with automatic samplers (ISCOs), grab samples, and field measurements during or immediately after two storm events in March 2006. These data generally indicate higher pollutant concentrations during or after storms, as described below. USGS has been collecting additional suspended sediment concentration data at the USGS gage, including storm samples. These samples also indicate higher concentrations during storm events.

Analyses of the stormwater and non-stormwater data included a comparison of water quality monitoring results to applicable WQC including summary statistics, spatial patterns, relationships between pollutants, and correlation to streamflow analyses. Results of these analyses are reported in the following sections.

4.3.1. Review of Impaired Segments

Several waterbody-pollutant combinations are included on the 2006 §303(d) list of impaired waterbodies (Table 2 and Appendix G). To further evaluate these waterbodies, all available water quality data were compared against the applicable water quality criteria. TMDLs, Informative TMDLs, or Load Targets were developed for each pollutant-waterbody combination, depending on the waterbody, pollutant, and listing status [i.e. TMDLs were developed for all combinations on the 2006 §303(d) list, while Informative TMDLs were calculated for most other combinations]. Table 10 summarizes the listing status, whether one of the criterion (single sample maximum and 30-day geometric mean for *enterococcus* and geometric mean, 10% NTE, and 2% NTE WQC for all other parameters) was exceeded based on data analyses, and how each waterbody-pollutant combination is being addressed as part of this current effort. The remainder of this section provides additional details regarding the data analyses performed to evaluate the exceedance of applicable WQC.

Table 10. Summary of Listings, Exceedances, and Current Application

Waterbody	Description	Entero	Turbidity	NH4	NOx	TN	TP	TSS
Estuary								
Hanalei River Estuary	Included on 2006 303(d) list[a]	Y	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	**TMDL**	**Verification**	IT	IT	IT	IT	**TMDL**
Waioli Stream Estuary	Included on 2006 303(d) list[a]	N	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waipa Stream Estuary	Included on 2006 303(d) list[a]	N	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	—	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waikoko Stream Estuary	Included on 2006 303(d) list[a]	N	Y	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Stream								
Hanalei River	Included on 2006 303(d) list[a]	Y	D	N	N	N	N	N
	Criteria exceeded[b]	√	W/D		—	W	W	W
	Current application[c]	**TMDL**	**Verification**	LT	IT	IT	IT	**TMDL**
Waioli Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	—	LT	IT	IT	IT	IT
Waipa Stream	Included on 2006 303(d) list[a]	N	**D**	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	**Verification**	LT	IT	IT	IT	**TMDL**
Waikoko Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	no data		no data	no data	no data	no data
	Current application[c]	IT	—	LT	IT	IT	IT	IT

[a]Y = year-round impairment; D = dry season impairment; W = wet season impairment; N = not listed

[b]For estuaries, exceedances are associated with year-round criteria (√). For streams, *enterococcus* is associated with year-round criteria (√), but all other parameters have separate wet (W) and dry (D) season standards that can be exceeded. These letters indicate that one or more of the applicable WQC were exceeded (additional details regarding these exceedances are presented in Table 11. Shading indicates no applicable standard. Waterbody-pollutant combinations not exhibiting any exceedances in the available data are represented by "–."

[c]TMDL = TMDLs were calculated as part of the current application; Verification = data and model output were used to confirm impairments and/or verify attainment of WQC through TSS TMDL implementation; IT = Informative TMDLs were calculated as part of the current application. LT = Load Targets were calculated as part of the current application; Waterbody-pollutant combinations not specifically addressed by any loading calculations are represented by "–."

To expand on the previous summary, observed bacteria, sediment, and nutrients data in the estuaries and streams were compared to their applicable WQC to determine exceedances of the standards. Data for individual stations were combined by waterbody. Figure 6.6 illustrates the stations used; however, all parameters were not sampled at all stations. The point symbols indicate how the stations were grouped (i.e. stream, estuary, etc.), while the color coding for the watershed boundaries indicates the waterbody with which they are associated. Water quality data were provided from HIDOH (HIDOH, 2006) and the Hanalei Watershed Hui (Berg, 2006). These analyses characterize the water quality data and quantify exceedances of the water quality criteria. The estuary and stream analyses are presented below.

Estuary data were compared against their applicable estuary WQC to evaluate the magnitude of *enterococcus* (30-day geometric mean and single sample maximum WQC), turbidity (geometric mean, 10% NTE, and 2% NTE WQC), and nutrients (geometric mean, 10% NTE, and 2% NTE WQC) exceedances. These analyses are presented in Figures A-1 through A-28 of Appendix A. For comparative purposes, estuary TSS data were compared against the stream WQC because no WQC exists for TSS in estuaries. A summary of the percent exceedances for each WQC calculated from these analyses is presented in Table 11 with the number of measurements included in parentheses (for the geometric mean WQC, the number of measurements is equal to the number of geometric means calculated, but for the single sample maximum and not-to-exceed WQC, these values are equal to the sample sizes). Essentially, the data confirm all current estuary impairments (*enterococcus* in the Hanalei River Estuary and turbidity in all four estuaries). In addition, several other pollutant-waterbody combinations consistently exceeded one or more of the WQC.

For all four estuaries, *enterococcus* concentrations exceeded both the geometric mean (based on a running 30-day geometric mean) and single sample maximum WQC regularly; however, only the Hanalei River Estuary is on the 303(d) list for *enterococcus* [(as discussed previously (Table 4), Informative TMDLs for *enterococcus* were developed for the other estuaries that are not currently listed). This trend also persists for the geometric mean and both not-to-exceed standards for turbidity. While nutrients are not currently on the §303(d) list for any of the waterbodies studied, the data indicate that the ammonia, nitrite plus nitrate, and total phosphorous WQC are consistently exceeded in all five estuaries. Exceedances of the total nitrogen WQC are less consistent. For example, data associated with the Hanalei River, Waioli Stream, and Waipa Stream Estuaries do not exceed the total nitrogen geometric mean, while data indicate that the Waikoko Stream Estuary exceeds it. The two not-to-exceed criteria are exceeded for total nitrogen in all estuaries (percent exceedances range from 4 to 27%) except for the 2% not-to-exceed criteria in the Waipa Stream Estuary. There is currently no TSS standard for estuaries; however, estuary TSS data were compared to the stream standards for comparative purposes. These estuary data routinely exceed the stream not-to-exceed TSS criteria (but at varying frequencies), but only the Waikoko Stream Estuary exceeds the TSS geometric mean stream criteria. As stated previously, these analyses confirm the existing impairments in the estuaries and also identify several other pollutant-waterbody combinations that are exceeding the WQC, although sample sizes for some parameters are small (less than 25 samples) and, therefore, more data are needed to draw more definitive conclusions (Table 11).

Stream data were also compared against their applicable freshwater WQC to evaluate the magnitude of *enterococcus* (30-day geometric mean and single sample maximum WQC), turbidity (wet and dry season WQC for geometric mean, 10% NTE, and 2% NTE), and nutrient (wet and dry season WQC for geometric mean, 10% NTE, and 2% NTE WQC) exceedances. These analyses are presented in Figures A-29 through A-62 of Appendix A. For comparative purposes, stream ammonia data were compared against the estuary WQC because no WQC exists for ammonia in streams. Similar to the estuary analyses, a summary of the percent exceedances for each WQC calculated from these analyses is presented in Table 11. The separate wet and dry season WQC were compared against data collected during their associated months. Essentially, the data confirm the current stream impairment for turbidity in Hanalei Stream and Waipa Stream and, similar to the estuary analyses, additional pollutant-waterbody combinations exceeding one or more of the WQC.

The stream analyses showed similar results for *enterococcus* and turbidity when comparing observed data to the various WQC; however, the percent exceedances were generally lower than those in the estuary (Figures A-29 through A-62 of Appendix A and Table 11). Data for Hanalei Stream indicate that the turbidity geometric mean criteria were exceeded during both wet and dry seasons [although the 2006 §303(d) listing is only for dry season exceedance], while data for Waipa Stream wholly confirm the dry season-only listing. In Hanalei Stream the 10% not-to-exceed criteria were exceeded 43% and 35%, respectively, for the wet and dry season and the 2% not-to-exceed criteria were exceeded 7% of the time during the wet season and 24% of the time during the dry season. In Waipa Stream the 10% not-to-exceed criteria were exceeded 0% and 13%, respectively, for the wet and dry season and the 2% not-to-exceed criteria were not exceeded at all. No *enterococcus* data were available for the freshwater portions of Waioli, Waipa, and Waikoko Streams; therefore, the only exceedances presented are those for Hanalei Stream (82% exceedance of the geometric mean WQC and 41% exceedance of the single sample maximum criteria). Nutrient and TSS data were less consistent; however, they do show exceedances of some WQC. Specifically, total nitrogen, total phosphorous, and TSS show exceedances of the not-to-exceed criteria in Hanalei Stream.

Table 11. Percent Exceedances Associated with Comparing Observed Data to WQC

Water-body	Water Quality Criteria[a]	Percent Exceedance of Numeric WQC by Parameter (number of measurements)[b,c] Entero	Turbidity	NH_4	NO_x	TN	TP	TSS
Estuary Comparisons								
Hanalei River Estuary	Geometric mean	99 (804)	100 (1)	100 (1)	100 (1)	0 (1)	100 (1)	0 (1)[d]
	SSM	75 (867)	N/A	N/A	N/A	N/A	N/A	N/A
	10% NTE	N/A	78 (702)	56 (59)	32 (59)	12 (59)	15 (59)	21 (66)[d]
	2% NTE	N/A	51 (702)	37 (59)	20 (59)	12 (59)	12 (59)	11 (66)[d]
Waioli Stream Estuary	Geometric mean	100 (262)	100 (1)	100 (1)	100 (1)	0 (1)	100 (1)	0 (1)[d]
	SSM	91 (286)	N/A	N/A	N/A	N/A	N/A	N/A
	10% NTE	N/A	54 (169)	83 (23)	74 (23)	4 (23)	13 (23)	9 (22)[d]
	2% NTE	N/A	38 (169)	65 (23)	52 (23)	4 (23)	4 (23)	5 (22)[d]
Waipa Stream Estuary	Geometric mean	100 (261)	100 (1)	100 (1)	100 (1)	0 (1)	100 (1)	0 (1)[d]
	SSM	86 (285)	N/A	N/A	N/A	N/A	N/A	N/A
	10% NTE	N/A	77 (167)	74 (23)	39 (23)	9 (22)	9 (22)	9 (22)[d]
	2% NTE	N/A	41 (167)	43 (23)	17 (23)	0 (22)	5 (22)	0 (22)[d]
Waikoko Stream Estuary	Geometric mean	100 (215)	100 (1)	100 (1)	100 (1)	100 (1)	100 (1)	100 (1)[d]
	SSM	96 (236)	N/A	N/A	N/A	N/A	N/A	N/A
	10% NTE	N/A	99 (167)	100 (23)	70 (23)	27 (22)	41 (22)	9 (22)[d]
	2% NTE	N/A	96 (167)	91 (23)	52 (23)	9 (22)	14 (22)	5 (22)[d]

Water-body	Water Quality Criteria[a]	Percent Exceedance of Numeric WQC by Parameter (number of measurements)[b,c] Entero	Turbidity Wet	Turbidity Dry	NH_4	NO_x Wet	NO_x Dry	TN Wet	TN Dry	TP Wet	TP Dry	TSS Wet	TSS Dry
Stream Comparisons													
Hanalei River	Geometric mean	82 (115)	100 (1)	100 (1)	100 (1)[e]	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
	SSM	41 (155)	N/A		N/A	N/A		N/A		N/A		N/A	
	10% NTE	N/A	43 (145)	35 (143)	6 (31)[e]	0 (19)	0 (11)	16 (19)	0 (11)	16 (19)	0 (11)	16 (19)	0 (10)
	2% NTE	N/A	7 (145)	24 (143)	0 (31)[e]	0 (19)	0 (11)	5 (19)	0 (11)	16 (19)	0 (11)	16 (19)	0 (10)
Waioli Stream	Geometric mean	no data	0 (1)	100(1)	100 (1)[e]	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
	SSM		N/A		N/A	N/A		N/A		N/A		N/A	
	10% NTE	N/A	0 (5)	0 (9)	0 (7)[e]	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)
	2% NTE	N/A	0 (5)	0 (9)	0 (7)[e]	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)
Waipa Stream	Geometric mean	no data	0 (1)	100 (1)	100 (1)[e]	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
	SSM		N/A		N/A	N/A		N/A		N/A		N/A	
	10% NTE	N/A	0 (6)	13 (8)	0 (14)[e]	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)
	2% NTE	N/A	0 (6)	0 (8)	0 (14)[e]	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)
Waikoko Stream	Geometric mean	no data	no data		no data	no data		no data		no data		no data	
	SSM		N/A		N/A	N/A		N/A		N/A		N/A	
	10% NTE	N/A	no data		no data	no data		no data		no data		no data	
	2% NTE	N/A	no data		no data	no data		no data		no data		no data	

[a]The *enterococcus* geometric mean is based on a 30-day running average, while the geometric mean for the other parameters is based on the entire dataset (i.e. a single geometric mean was calculated). The number of measurements is equal to the number of geometric means calculated.

[b]Abbreviations: Entero = *enterococcus*; NH_4 = Ammonia; NO_x = nitrite plus nitrate; TN = total nitrogen; TP = total phosphorous; TSS = total suspended solids; N/A = not applicable

[c]Red bold font indicates an exceedance of the water quality criteria. For the 10% and 2% not-to-exceed criteria, fonts were changed if the percent exceedance of the numeric standard is greater than 10% or 2%, respectively.

[d]There is no estuary WQC for TSS. For comparative purposes, the estuary TSS analyses are based on the dry stream.

[e]There is no stream WQC for ammonia. For comparative purposes, the stream ammonia analyses are based on the estuary WQC.

4.3.2. Trends and Relationships

Several different analyses were conducted to obtain a better understanding of the conditions contributing to water quality problems. These include spatial analyses, stream flow and water quality comparisons, and correlative analyses between parameters.

4.3.2.1. Spatial Trends

To evaluate spatial trends on the Hanalei River, data for each pollutant were graphed at all in-stream monitoring stations (see Figure 6.6) from upstream to downstream. These graphs are presented in Figure 88 through Figure 14. Freshwater stations are shown in blue and the estuary stations are shown in yellow. Essentially, just downstream of the Upper ISCO station, the system changes from non-tidal (freshwater) to tidal (estuary). The bars in these figures illustrate the geometric mean values, while the error bars represent the minimum and maximum observed values.

These graphs presented in Figure 88 through Figure 14only suggest a general trend in the data collected through the Hanalei River and its estuary and this trend is less pronounced in the *enterococcus* and sediment measurements. In general, the estuary stations have higher geometric mean values than the freshwater stations; however, the ranges illustrate that high (or low) observations can occur throughout the system. In most cases, only a few samples were available for each station; therefore, the results at these stations carry much less weight than the stations with larger sample sizes. When only evaluating the stations with more than 20 samples, the upstream to downstream increase in geometric mean concentrations is gradual for all pollutants other than ammonia, which has a much larger increase upstream to downstream. In addition, it is difficult to directly compare these results without having a better understanding of the temporal distribution of data with respect to storm events. Despite these limitations, it is useful to have a general understanding of the spatial distribution of water quality results in the Hanalei River watershed and because the pollution sources are similar in the Waioli, Waipa, and Waikoko Stream watersheds, similar patterns can be expected in those watersheds. Spatial trends for each pollutant are described below.

For *enterococcus*, the results are presented on a logarithmic scale (Figure 8). Overall, the freshwater geometric mean observations are slightly lower than the estuarine values; however, the geometric mean concentrations at all stations were generally within an order of magnitude. The geometric mean at the Upper ISCO freshwater station is about an order of magnitude higher than the other freshwater stations. Data for the Upper ISCO station were generally high across all parameters. This may be due to the sample timing (these samples were collected immediately after a storm; therefore, it is expected that the results would have higher concentrations) or it may be caused by specific conditions in the watershed on those sample dates or sampling error. Closer evaluation of the data at the USGS station indicates that the high maximum value is associated with a sample event in December 2003 with an extremely high *enterococcus* reading (24,196 cfu/100 milliliters [mL]). Even with this high value, the geometric mean is similar to the geometric means at the other freshwater stations. The Lower ISCO estuary station was sampled during the same events and follow similar pattern as the Upper ISCO station. While many of the samples at the other stations were collected during the wet season, they were not necessary corresponding to a storm event (depending on parameter, between 10 and 30 percent of samples were collected on high-flow days; Table 8).

The TSS results (Figure 99) follow a similar pattern to the *enterococcus* results. Specifically, the geometric mean freshwater values are lower than those collected in the estuarine portion of the Hanalei River, with the obvious exception of the Upper ISCO station, which, as described above, was sampled during or immediately after a storm event. The turbidity results (Figure 10) are also impacted by the high value at the Upper ISCO station. Except for the Upper ISCO station, the geometric mean values are below 20 NTU for turbidity; however, the maximum values are generally high among all stations. If this station, which only has two samples associated with it, is removed from the analyses, the geometric means at the other stations clearly show that the estuary has higher values than the freshwater segment.

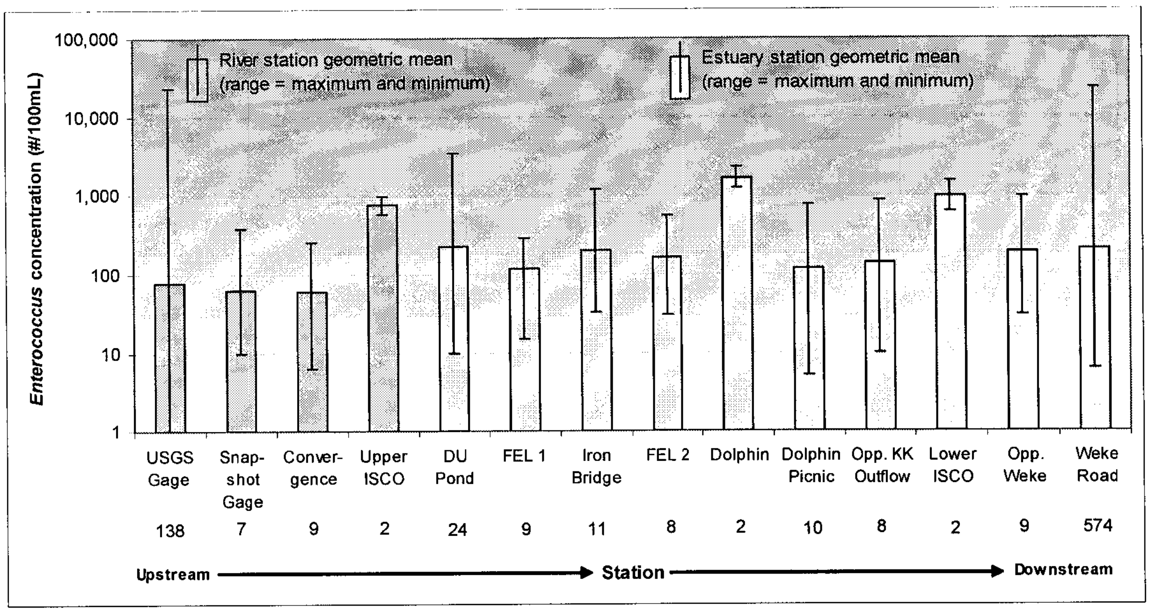


Figure 8. Upstream to downstream *enterococcus* concentrations on the Hanalei River

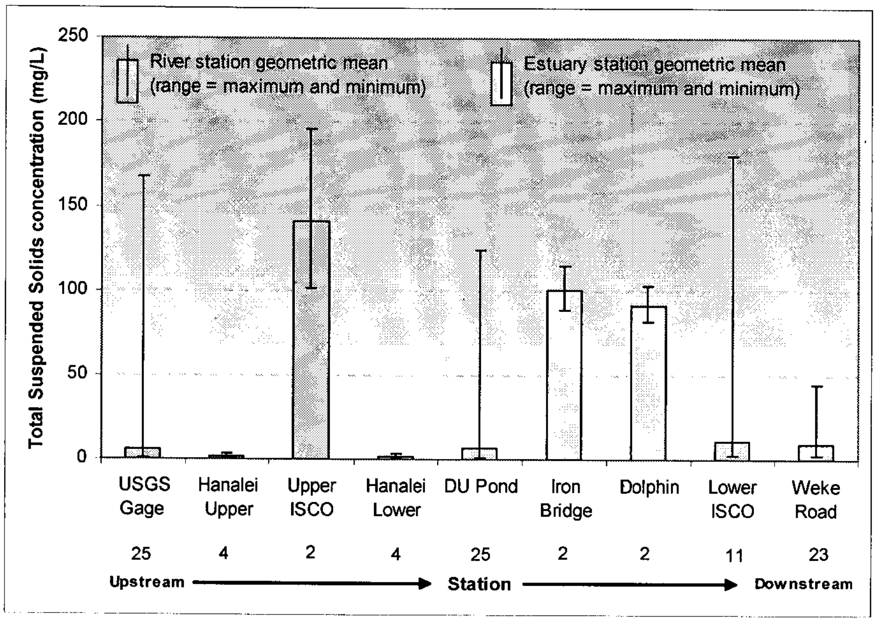


Figure 9. Upstream to downstream total suspended solids concentrations on the Hanalei River

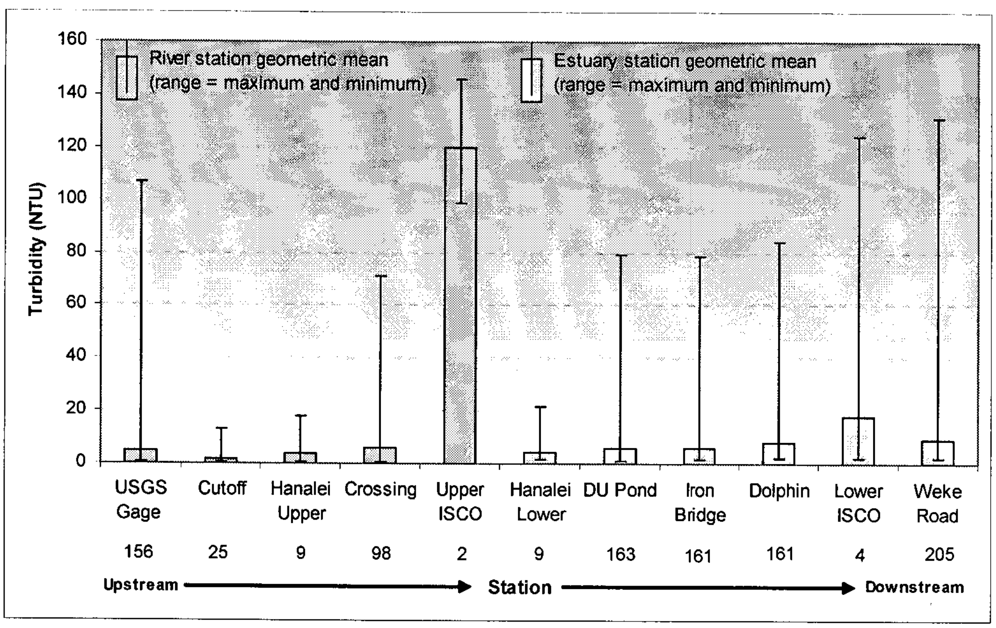


Figure 10. Upstream to downstream turbidity on the Hanalei River

The nutrient results follow the same general relationship described above; however, the upstream to downstream patterns are more pronounced. Figure 11 through Figure 14 illustrate the number, geometric mean, minimum, and maximum values for ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous, respectively. Elevated concentrations at the Upper ISCO station are more prominent in the total nitrogen and total phosphorous graphs, when compared to ammonia and nitrite plus nitrate.

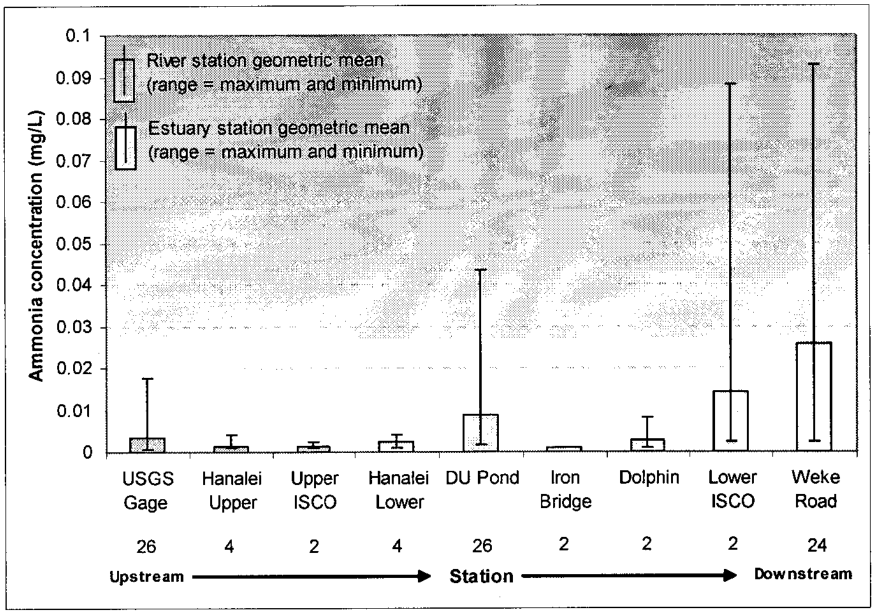


Figure 11. Upstream to downstream ammonia concentrations on the Hanalei River

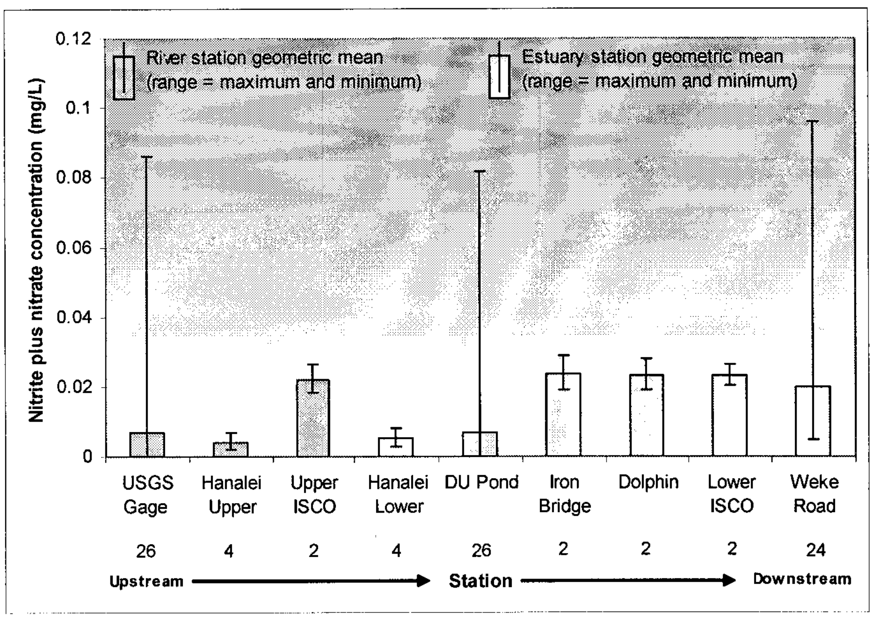


Figure 12. Upstream to downstream nitrite plus nitrate concentrations on the Hanalei River

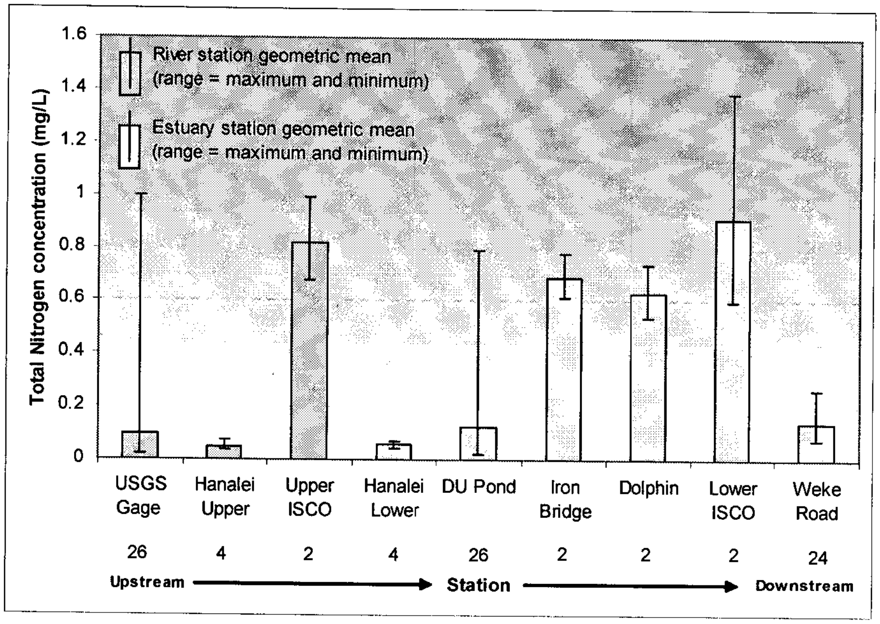


Figure 13. Upstream to downstream total nitrogen concentrations on the Hanalei River

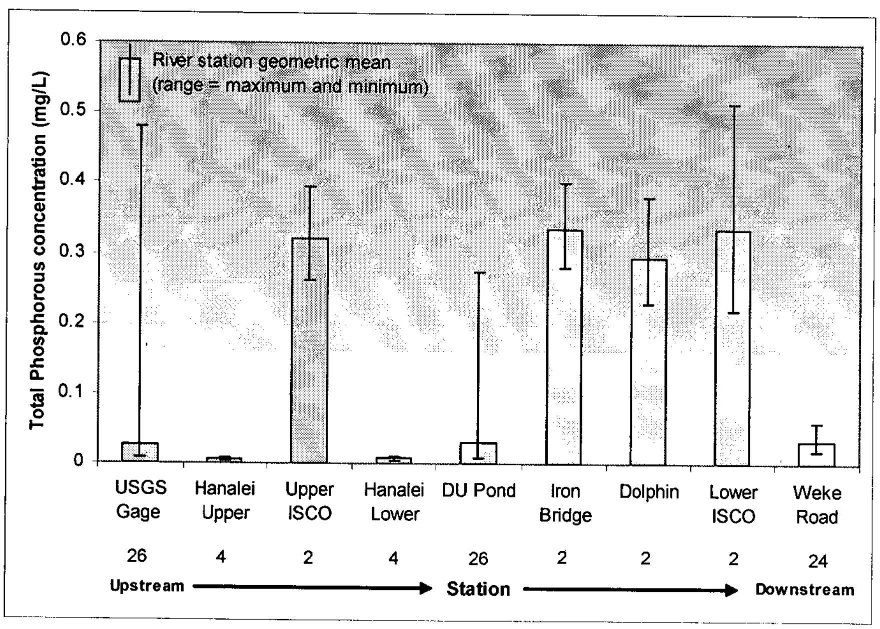


Figure 14. Upstream to downstream total phosphorous concentrations on the Hanalei River

Available *enterococcus* and turbidity data collected in the ditches and drainage culverts, which collect runoff throughout the agricultural areas and act as tributary inflows, were also evaluated. For these analyses, data for all stations in the Hanalei River Estuary were combined and summary statistics were calculated and are presented in Table 12. When the drainage culvert data are considered collectively, the geometric mean *enterococcus* value of 192 cfu/100 mL is higher than the geometric mean of eight of the 14 stations illustrated in Figure 88 (geometric means for the 14 stations range from 60.3 to 965.9

cfu/100 mL). However, the drainage culvert and in-stream geometric mean values are all within the same order of magnitude. The maximum *enterococcus* value in the drainage culverts was higher than 12 of the 14 stations shown in Figure 88. For turbidity, the geometric mean value in the drainage culverts is greater than six of the 11 stations identified in Figure 10 and its maximum is greater than seven out of the 11 stations. These data suggest that the drainage culverts are likely contributing to the high *enterococcus* and turbidity levels in the Hanalei River Estuary, especially under specific conditions that may be causing higher values; however, when combined into a single dataset the drainage culvert values are not significantly higher than those observed in-stream (i.e. the *enterococcus* concentrations are within the same order of magnitude). Unfortunately, nutrients data in the drainage culverts were not available to assess ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous concentrations.

Table 12. Summary Statistics for Drainage Culvert Monitoring Stations

Parameter	Sampling Period	Number of Samples	Summary Statistics			
			Minimum	Maximum	Geometric Mean	Median
Enterococcus (cfu/100mL)	11/14/00-5/18/06	211	7	11,199	192	161
Turbidity (NTU)	4/12/03-5/18/06	840	0.48	90.60	6.15	6.29

4.3.2.2. Streamflow Correlations

To further understand the impact of stream flow on water quality in the Hanalei River, a statistical comparison of flow versus each pollutant was performed. Specifically, flow data for the USGS Hanalei River gage (station 1610300) were compared with water quality data at the same location. Because this is the only station with flow measurements that overlap with the water quality data, these flow results were also compared with water quality data at the Weke Road station near the mouth of the estuary. Although these flow measurements are not directly comparable, they provide a reasonable relative comparison, especially during storm events.

Figures A-63 through A-70 of Appendix A show the flow and water quality comparisons at the USGS gage, while Figures A-71 through A-77 of Appendix A illustrate the results using the Weke Road water quality data. Each figure presents the results of two analyses: flow-associated trend assessment and seasonal trend assessment. The flow-associated analyses illustrate the flow-weighted concentrations for all samples within a flow percentile and can be used to identify trends in pollutant levels associated with different flow regimes. The seasonal analyses show flow-weighted concentrations for all samples collected in the same month of the year, which helps to identify monthly or seasonal differences that may be caused by seasonal land management activities or environmental conditions.

In general, high *enterococcus* levels were observed at the highest flows, but there was no clear seasonal pattern as high concentrations can occur in any month. The sediment-related data (turbidity, TSS, and suspended sediment concentration [SSC]), followed similar patterns. Specifically, there were higher values observed during high flow conditions and no seasonal pattern, except that the values during the wet season were generally slightly higher than the other months for TSS (this seasonal pattern only persists for January through March for SSC; however, it should be noted that the SSC data collected after September 2005 was considered provisional at the time of analysis). Ammonia and nitrite plus nitrate did not follow any obvious flow-associated or seasonal patterns, with the exception of consistently high nitrite plus nitrate values in December. The total nitrogen and total phosphorous analyses at the USGS station indicated that higher concentrations were observed under higher flow conditions and there was no clear seasonal pattern except for elevated concentrations in March.

Data for the same parameters at Weke Road showed much wider variability. In general, the total nitrogen results increased along with flow and concentrations were generally higher during the wet season when compared to the dry months. Total phosphorous at Weke Road followed the same seasonal pattern; however, there was no discernable flow-associated trend. These analyses indicate that high concentrations are observed year round, suggesting that critical conditions can occur during any month. Therefore, it is important to consider each WQC throughout the course of the year. It should be noted that there were high water quality concentrations during December 2003 for several pollutants collected at both stations that are weighting the analyses towards the high flow-high concentration pattern. It is assumed that these samples were collected during or after a storm event, thereby resulting in high concentrations (and loads), because they are similar in magnitude to the post-storm samples collected at the ISCO stations (described in Section 4.3.2.1).

4.3.2.3. Correlative Analyses

To evaluate the relationships between water quality parameters, correlative analyses were performed. These analyses indicate that TSS and turbidity are strongly correlated in the Hanalei Bay watershed, with an R^2 value of 0.7175 (Figure 15) based on 183 samples (collected by HIDOH and the Hui); thus justifying the use of TSS as a surrogate for turbidity in the calculation of TMDLs and load targets. This strong relationship is particularly evident at lower observed values (which are generally associated with lower flows) and become less predictable at higher values (which are generally associated with higher flows [see Figure A-49 and A-50 of Appendix A for turbidity and TSS flow comparisons, respectively, at the USGS gage]). An independent analysis performed by the Hui on their TSS and turbidity data collected from November 2003 through April 2004 verifies this correlation (Berg et al., 2004).

The TSS and turbidity data used for this correlation, which came from all four watersheds, two waterbody types (stream and estuary), and two seasons (wet and dry), were evaluated several different ways according to these characteristics. Although the results showed some variability in the resulting TSS values, we judged the use of a larger, combined dataset to establish a single regression that reflects the mid-range of all the correlations and corresponding TSS values as the most reasonable choice for the current analysis. However, careful reevaluation of the numeric targets for turbidity endpoints, including more robust multivariate analysis of turbidity and TSS correlations, will be conducted during the next phase of TMDL development, with subsequent changes to the loading analysis as necessary in future revisions of the TMDL decision.

Upon evaluation of the available data collected on concurrent days, it was determined that *enterococcus* was not linearly related to TSS ($R^2 = 0.039$). However, observed data indicate that total phosphorous and total nitrogen concentrations have a strong relationship with sediment concentrations ($R^2 = 0.8345$ and 0.7293, respectively); however, ammonia and nitrite plus nitrate did not have a strong correlation ($R^2 = 0.0001$ and 0.0033, respectively; Figure 16). Because ammonia and nitrite plus nitrate did not exhibit a relationship to sediment, it was assumed that organic nitrogen was causing the strong correlation.

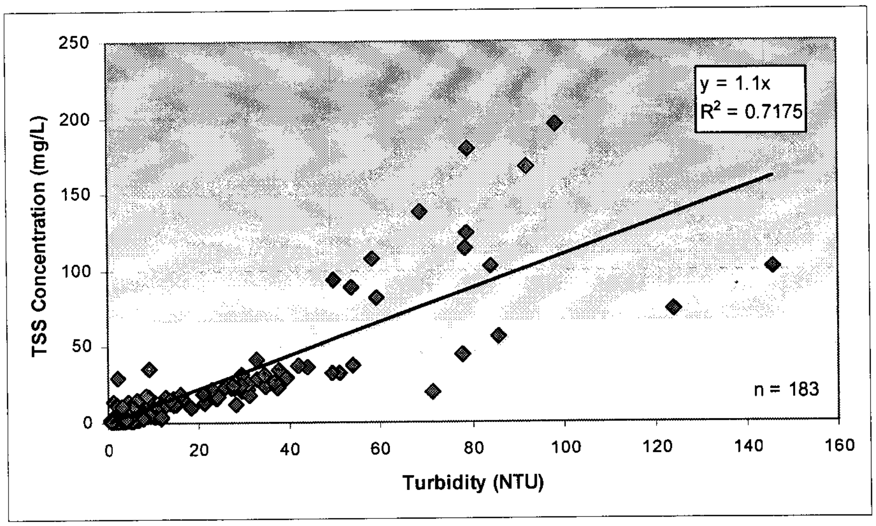


Figure 15. Turbidity and TSS relationship in the Hanalei Bay watershed

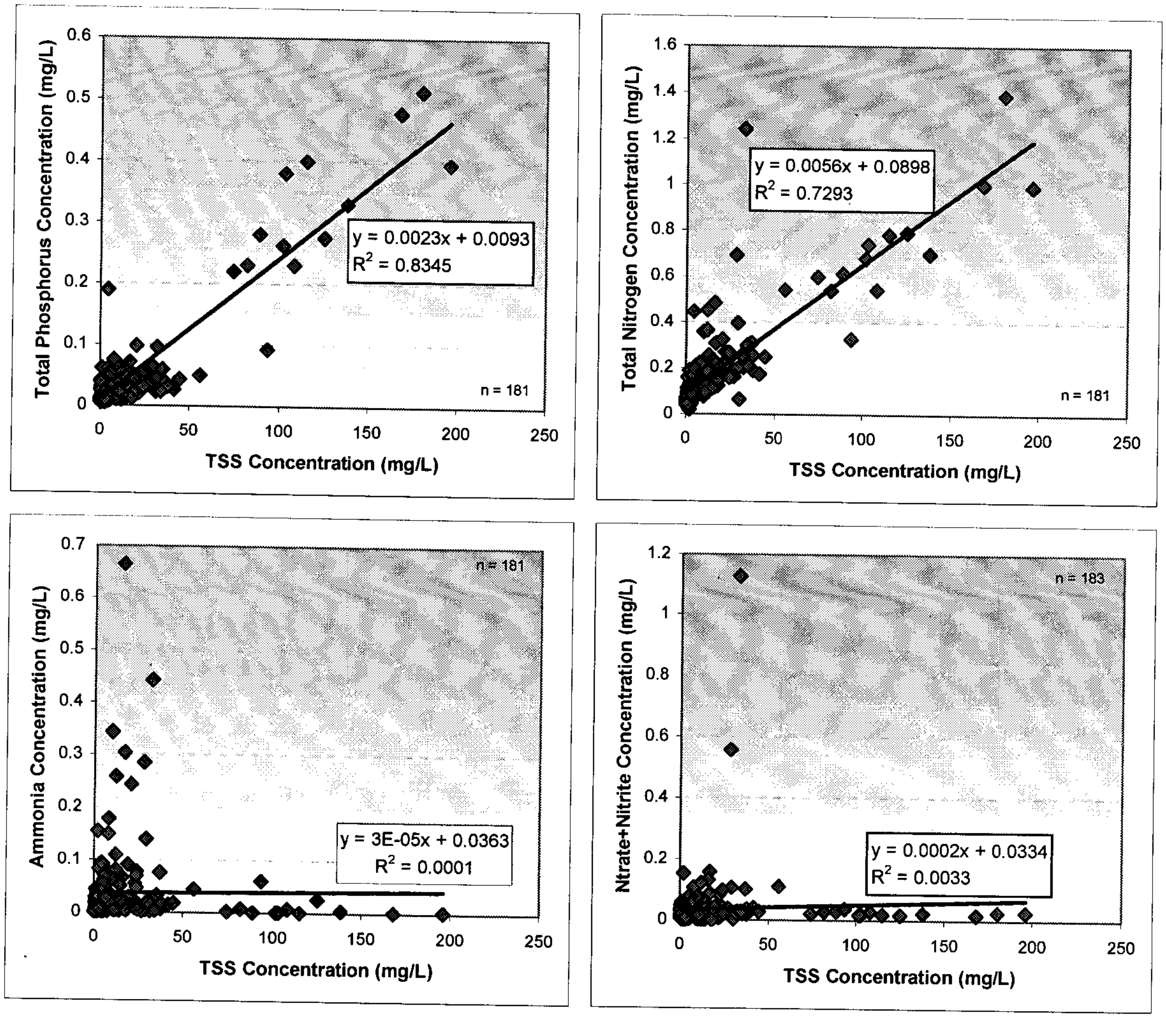


Figure 16. Relationships between sediment and nutrients

5. Source Analysis

The purpose of the source analysis is to identify and quantify the sources of pollutants to the impaired waterbodies. In-stream and watershed data were used to identify potential sources and characterize the relationship between point and nonpoint source loadings and in-stream response, under both wet and dry seasons. Point sources typically discharge at a specific location from pipes, outfalls, and conveyance channels from, for example, municipal wastewater treatment plants, or municipal separate storm sewer systems (MS4s). Nonpoint sources, including groundwater, are diffuse sources that have multiple routes of entry into surface waters. In Hawai'i, groundwater occurs as either basal or high-level groundwater. Basal groundwater is groundwater floating on and displacing seawater, while high-level groundwater is impounded within compartments formed by impermeable dikes or on low-permeable layers. The basal groundwater in Hanalei likely discharges to marshy areas and in-stream channels along the inland edge of the coastal plain without causing large visible springs (MacDonald et al., 1960). Much of the high-level groundwater in the Hanalei region is diffused in small springs and seeps in valley walls or stream channels with some sources (MacDonald et al., 1960). However, a recent study suggests that under certain conditions, groundwater may contribute up to 20 percent of the flow to Hanalei Bay (Knee et al., 2005, 2006).

During both wet weather and dry weather periods, multiple sources of bacteria, sediment, and nutrients associated with both natural and anthropogenic activities contribute to overall loads to the impaired waterbodies. Bacteria are deposited directly to the waterways and also onto land surfaces. The forested portion of the watershed includes unknown populations of feral pigs and goats as well as several species of birds (Griffin, 2000), which are potential sources of bacteria. In addition, bird populations in the Hanalei NWR have increased over the past thirty years (Asquith and Melgar, 1999) and introduced mammals such as feral cats, dogs, and rats on the Hanalei NWR are considered problem species (Berg et al., 1997). These wildlife populations are also potential sources contributing to elevated bacteria concentrations in the watershed. Further downstream from the Hanalei NWR, there are pastures with bison ranching (Berg et al., 1997) along with the town of Hanalei, which has no centralized waste treatment. Waste disposal is through onsite septic & cesspool systems except for small treatment plants that serve the commercial centers (Fujimoto, 1977; Griffin, 2000). All of these sources have the potential to contribute to the elevated *enterococcus* concentrations measured throughout the watershed. In addition, a groundwater study conducted in 2005 found that bacteria concentrations were lower in groundwater than in the Hanalei River, Hanalei Bay, and other streams; however, relatively high levels of *Escherichia coli* was detected in groundwater seaward of a cesspool. These findings suggest that groundwater is a potential a source of bacteria during periods of high discharge (Knee et al., 2005).

Sediment concentrations are also associated with both natural and anthropogenic activities. Although there are occasionally high erosion rates due to high precipitation and steep slopes in the headwaters, sediment loads from the headwaters are also associated with alteration of the forest landscape due to human inhabitants, introduction of feral livestock (pigs and goats), and alien tree and plant species (Griffin, 2000). Based on the evaluation of turbidity and suspended sediment data, sediment yields increase in the more downstream portions of the watershed (Berg et al., 1997). Specifically, sediment yields double through the Hanalei NWR and turbidity values increase as well (Berg et al., 1997). While sediment plumes have been observed in return flows to the Hanalei River, the total sediment load may be minor compared to the sediment generated during natural flood events (the Hanalei River load was estimated at 30-80 times the load from ditches and impoundments) (Berg et al., 1997).

Nutrients are also associated with a variety of land-based activities. The presence of wildlife in wetlands, grasslands, and forested areas, fertilization of agricultural areas, and various activities in urban areas are all potential sources of nutrients (Berg, 1995; Berg et al., 1997; USEPA, 2005; Schueler and Holland, 2000). Nutrients in the agricultural areas of the Hanalei River watershed have been previously studied by Berg (Berg et al., 1997; Berg, 1995). These studies concluded that due to fertilization of taro ponds, or lo'i, nitrogen loads in return waters were 4-40 times higher when compared to inflow waters on the Hanalei NWR (Berg et al., 1997). Other potential sources of nutrients, such as wildlife and urban activities (poor sewage treatment, residential fertilization, pet waste, etc.), are not quantified in the Hanalei Bay watershed; however, they are well documented sources of nutrients (USEPA, 2005; Schueler and Holland, 2000). Groundwater, which is influenced by several sources such as cesspools, agricultural areas, soil, and urban runoff, is also a potential source of nutrients to the Hanalei Bay watershed. Specifically, nutrient concentrations were found to be higher in groundwater than in the Hanalei River or other streams (Knee et al., 2005, 2006). Increased nutrients concentrations from upstream to downstream (i.e. freshwater to saltwater) are also confirmed by the data collected in the Hanalei River watershed, as presented in Section 4.3.2.1.

5.1. Point Sources

There are no NPDES dischargers that are major point sources of pollutants in the Hanalei Bay watershed. Therefore, no point sources are discussed in this Source Analyses and there no waste load allocations (WLA) are included in the TMDL.

5.2. Nonpoint Sources

In this analysis, pollutant sources were quantified by land cover type since loadings can be highly correlated with land-based activities (Figure 1717). For *enterococcus*, ammonia, and nitrite plus nitrate, wash-off of these pollutants from various land covers during wet weather events is considered the primary mechanism for transport. After they build up on the land surface as the result of various land sources and associated management practices, many of the pollutants are washed off the surface during rainfall events. The amount of runoff and associated pollutant concentrations are therefore highly dependent on land-based activities. This methodology of correlating land cover to *enterococcus*, ammonia, and nitrite plus nitrate sources produced successful modeling results. The methodology used for quantification of pollutant concentrations from various land cover types is discussed in the Modeling Report, Appendix B.

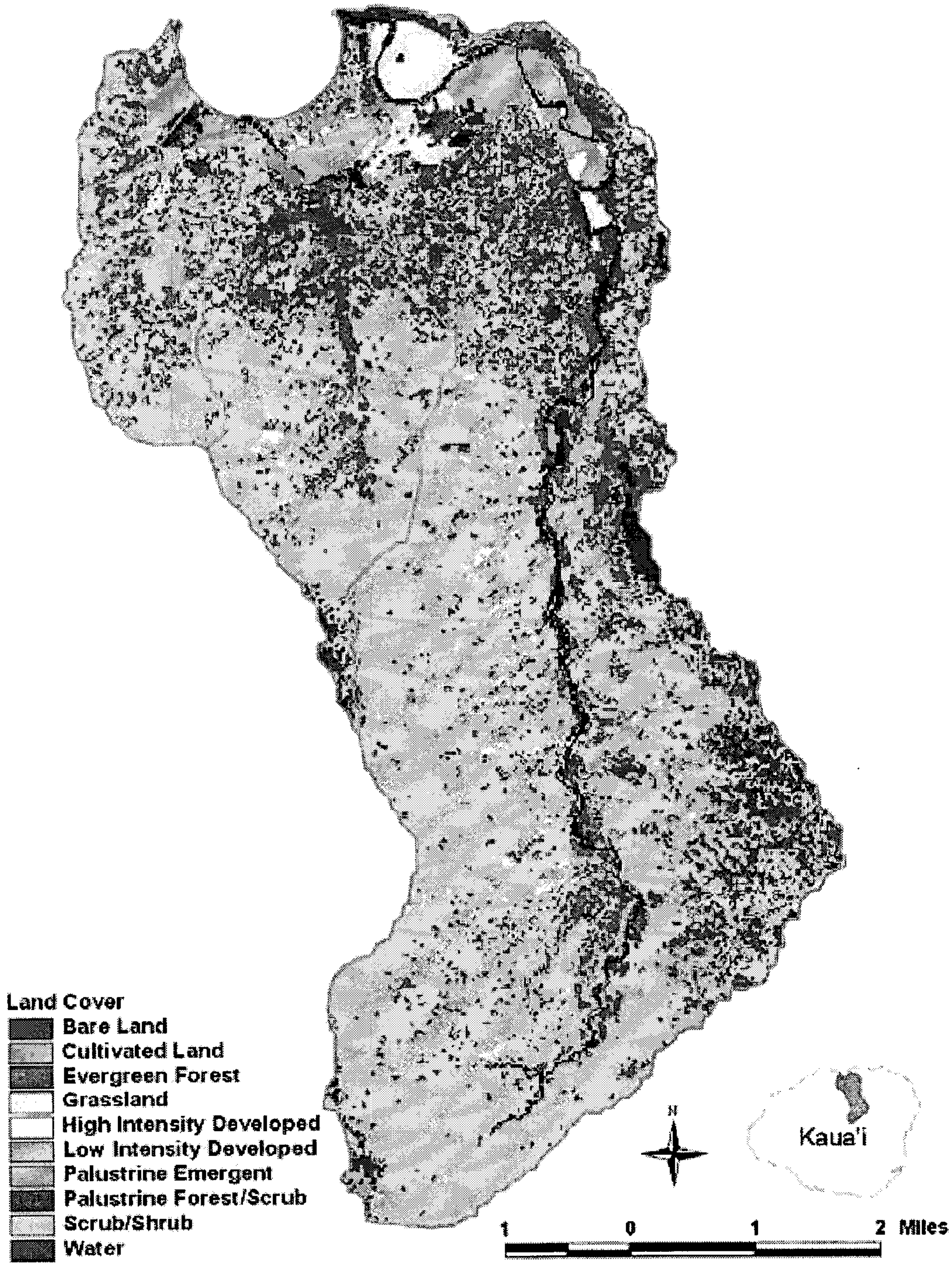


Figure 17. Land cover

Because the observed data indicated that total phosphorous and total nitrogen concentrations were strongly correlated to sediment concentrations (Figure 1616), these nutrients were represented through their association with sediment. Sediment production is highly dependent on land-based activities, while its wash-off depends on rainfall intensity and the amount of sediment available for removal. The ratio between total nitrogen and total phosphorous concentrations and total suspended sediment varies by land cover. This methodology is further described in Appendix B.

A series of charts were developed that show relative pollutant loads by land cover type for the Hanalei River, Waioli, Waipa, and Waikoko watersheds based on model results of existing conditions, which were calibrated to observed data (Appendix C). These results are summarized for the entire Hanalei Bay watershed in Table 13. In general, the scrub/shrub and evergreen forest land covers contribute a vast majority of the loads. This is not surprising given that they make up nearly 90% of the land cover area for the watershed (Figure 3). Existing bird impoundments overlapped with the palustrine emergent land cover and taro pondfields are generally located in the cultivated lands. While some land covers may contribute relatively high concentrations of certain pollutants, their impact on the overall loading (which is represented for the entire Hanalei Bay watershed in Table 13 and individually for the Hanalei River, Waioli, Waipa, and Waikoko watersheds in Appendix C) may be fairly minor due to their small land area and resulting runoff volume.

Table 13. Relative Loadings by Land Cover for the Hanalei Bay Watershed

Land cover category	Percent of total land area	Percent of total load					
		Enterococcus	TSS	Ammonia	Nitrite plus nitrate	Total nitrogen	Total phosphorous
Bare Land	0.1%	0.01%	0.1%	0.02%	0.04%	0.04%	0.05%
Cultivated Land	2.6%	2%	2%	64%	20%	6%	8%
Evergreen Forest	25.2%	27%	16%	6%	14%	17%	17%
Grassland	3.5%	0.4%	2%	1%	2%	1%	2%
High Intensity Developed	0.02%	0.1%	0.1%	0.01%	0.1%	0.003%	0.003%
Low Intensity Developed	0.8%	0.4%	1%	0.2%	1%	0.2%	0.2%
Palustrine Emergent	0.6%	7%	2%	4%	7%	3%	2%
Palustrine Forest/Scrub	1.7%	0.3%	2%	1%	1%	2%	2%
Scrub/Shrub	64.5%	63%	75%	24%	55%	70%	69%
Water	0.9%	0%	0.2%	0.1%	0.3%	0.3%	0.4%

The relative loadings presented in Table 13 are based on an accounting of overall gross loads from the calibrated model. As indicated by the second column in the above table, the land covers with the greatest relative land area generally contribute the highest relative loading. While many of the land covers with the highest area are often considered "background," anthropogenic sources also impact water quality in the system, as described below.

To further characterize pollutant sources in the watershed, *enterococcus* data collected on the same date at the USGS gage and Weke Road monitoring stations were reviewed. These stations were selected because they had a significant number of samples collected on the same date and their locations represent different sources in the watershed. The USGS gage is located upstream of nearly all anthropogenic activities, while the Weke

Road station is downstream of these activities and, therefore, represents the contributions of both the anthropogenic and natural sources in the Hanalei River watershed. To evaluate the upstream and downstream sources, the difference between the log of the *enterococcus* concentrations at Weke Road and the USGS gage were calculated (samples were collected on the same date). These results are presented for stormflow samples in Figure 18 and baseflow samples in Figure 19. Days were classified as baseflow or stormflow by obtaining average daily flow values at the USGS gage for January 1995 through May 2006. The days corresponding to the highest ten percent of flows were assigned to the stormflow category and all other days were assigned to the baseflow category.

The blue bars in both graphs represent dates on which the Weke Road *enterococcus* concentration was higher than the concentration at the USGS gage, while the orange bars represent higher concentrations at the USGS gage. These data indicate that there is clearly a difference between the concentrations at these two locations. Approximately 75 percent of all samples were higher at Weke Road than the USGS gage (represented by the blue bars in both graphs). Specifically, on storm days 15 of the 20 storm samples (75.0 percent) and during baseflow 78 of the 103 samples (75.7 percent) were higher at Weke Road. Similar analyses were performed by separating the data into wet (November through April) and dry (May through October) seasons. These results were consistent with the stormflow and baseflow analyses. Specifically, during the wet season, 53 of the 63 samples (84 percent) were higher at Weke Road than the USGS gage and during the dry season 40 of the 60 samples (67 percent) were higher at Weke Road. The anthropogenic sources draining to the Weke Road station are likely causing the higher concentrations observed at this station and these contributions are particularly influential during the wet season.

Figure 18. Difference between stormflow enterococcus values at Weke Road and USGS Gage

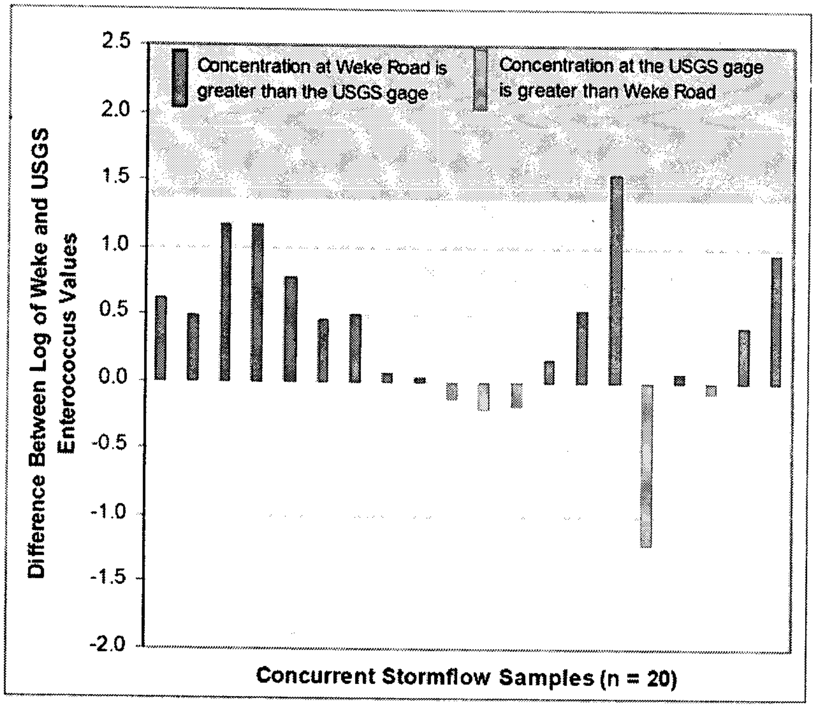
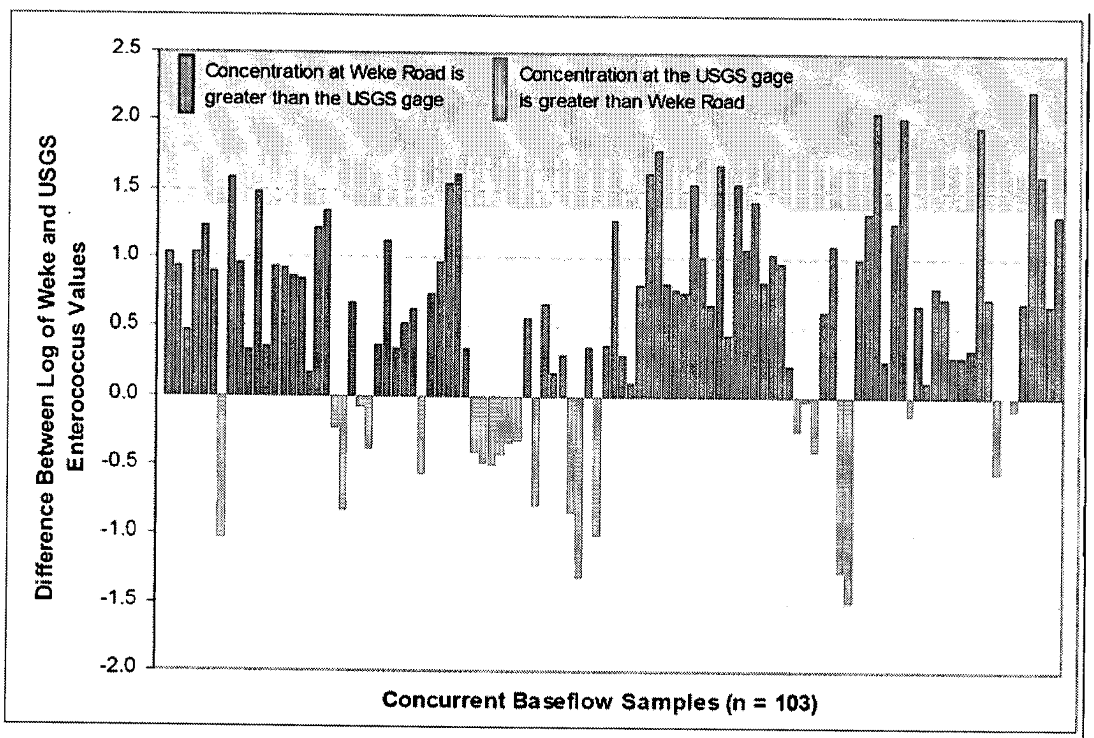


Figure 19. Difference between baseflow enterococcus values at Weke Road and USGS Gage



6. Linkage Analysis

The technical analysis of pollutant loading from watersheds and the receiving waterbody response to this loading is referred to as the linkage analysis. The purpose of the analysis is to quantify the maximum allowable loading for each pollutant to the impaired waterbody resulting in attainment of WQC. This value is in fact, the TMDL. TMDLs (or similarly calculated load targets) were calculated for each waterbody-pollutant combination described in Section 2 using model output. Because the numeric targets are set equal to the numeric WQC for *enterococcus*, turbidity, and nutrients, attainment of these numeric targets will result in attainment of WQC. The percent reduction from the total existing load needed in order to attain WQC was also calculated for each waterbody.

To support the TMDL objectives outlined by HIDOH and USEPA and using available data, the development of a comprehensive linked watershed/receiving water modeling system was necessary to represent the Hanalei Bay watershed system. A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring land-based processes over an extended period, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes using land-based calculations as input.

Receiving water models are composed of a series of algorithms applied to characteristics data to simulate flow and water quality of the waterbody. The characteristics data represent physical and chemical aspects of a lake, river, or estuary. These models vary from simple 1-dimensional box models to complex 3-dimensional models capable of simulating water movement, salinity, temperature, sediment transport, pollutant transport, and bio-chemical interactions occurring in the water column.

The remainder of this section describes the model selection criteria, the selected models, and general model application. The models were used to calculate both existing conditions and the TMDLs (or Informative TMDLs or Load Targets).

6.1. Model Selection Criteria

In selecting an appropriate modeling approach for TMDL calculation, technical, regulatory, and user criteria were considered. Technical criteria include the physical system in question, including watershed or receiving water characteristics and processes and the constituent(s) of interest. Regulatory criteria include WQC or procedural protocol. User criteria comprise the operational or economical constraints imposed by the end-user and include factors such as hardware/software compatibility and financial resources. The following discussion details the considerations in each of these categories. Based on these considerations, appropriate models were chosen to simulate watershed and receiving water conditions.

6.1.1. *Technical Criteria*

The watershed and surface waters of the Hanalei Bay watershed system present a challenging system for modeling hydrology and water quality. This section outlines key functions and processes that are necessary for consideration in the selection of an appropriate modeling strategy. These technical criteria are divided into three main topics: physical domain, source contributions, and constituents. Consideration of each topic was critical in selecting the most appropriate modeling system to address the types of sources and the numeric targets associated with the impaired waters.

6.1.1.1. Physical Domain

Representation of the physical domain is perhaps the most important consideration in model selection. The physical domain is the focus of the modeling effort – typically described by either the receiving water itself or a combination of the contributing watershed and the receiving water. Selection of the appropriate modeling domain depends on the constituents of interest and the conditions under which the receiving water exhibits impairment. For a receiving water dominated by point source inputs that exhibits impairments under only low-flow conditions, a steady-state approach is typically used. This type of modeling approach focuses on only in-stream (receiving water) processes during a user-specified condition. For receiving waters affected additionally or solely by rainfall-driven flow and pollutant contributions, a dynamic approach is recommended.

Dynamic models consider time-variable nonpoint source contributions from a watershed surface or subsurface, or throughout the water column of a receiving water body. Some models consider monthly or seasonal variability, while others enable assessment of conditions immediately before, during, and after individual rainfall events. Dynamic models require a substantial amount of information regarding input parameters and data for calibration purposes. The Hanalei River watershed is dominated by rainfall-driven flow and pollutant contributions that deposit directly to tributaries and their receiving waters.

6.1.1.2. Source Contributions

Primary sources of pollution to a waterbody must be considered in the model selection process. Accurately representing contributions from permitted point sources and nonpoint source contributions from urban, agricultural, and natural areas is critical in properly representing the system and ultimately evaluating potential load reduction scenarios.

Water quality monitoring data were not sufficient to fully characterize all sources of bacteria, sediment, and nutrients in the watersheds draining to impaired waterbodies. However, analyses of the available data indicate that the main sources are open areas, runoff from agriculture, and bird impoundments. Watershed sources can be addressed through the model calibration and validation process and major source categories considered controllable for TMDL implementation purposes can be simulated based on varying assumptions for management scenarios.

6.1.1.3. Constituents

Another important consideration in model selection and application is the constituent(s) to be assessed. Choice of state variables is a critical part of model application. The more state variables included, the more difficult the model is to apply and calibrate. However, if key state variables are omitted from the simulation, the model might not simulate all necessary aspects of the system and might produce unrealistic results. A delicate balance must be met between minimal constituent simulation and maximum applicability.

The focus of development of this study is on *enterococcus*, turbidity, and nutrients (specifically, total nitrogen, total phosphorous, ammonia, and nitrite plus nitrate). Factors affecting the survival of *enterococcus* bacteria include soil moisture content, pH, solar radiation, and available nutrients. In-stream bacteria dynamics can be extremely complex, and accurate estimation of bacteria concentrations relies on a host of interrelated environmental factors. Bacteria concentrations in the water column are influenced by die-off, regrowth, partitioning of bacteria between water and sediment during transport, settling, and resuspension of bottom materials. First-order die-off is likely the most important dynamic process to simulate as it represents all unknown bacteria losses, despite observations that bacteria regrow in certain conditions (Byappanahalli and Fujioka, 1998).

Turbidity cannot be directly simulated using most watershed and receiving water models. A turbidity load cannot be calculated because its measurements are not mass-based. To overcome this limitation, a mass-based surrogate must be used during model development. Because turbidity and TSS had a strong relationship, as described in Section 4.3.2.3, TSS was considered a suitable surrogate for model application.

Nutrient cycling is extremely complex and accurate estimation of nutrient loading relies on a host of interrelated factors. The transport of nutrients from point of origin into stream channels, from streams into their estuaries, and ultimately within the estuaries, is also influenced by multiple factors. The relative impact of external nutrient loading to the estuaries and internal loading must be represented by the modeling system.

6.1.2. Regulatory Criteria

A properly designed and applied model provides the source-response linkage component of the TMDL and enables accurate assessment of assimilative capacities and allocation distribution. A waterbody's assimilative capacity is determined by assuming adherence to WQC. The HAR establishes, for all waters in the State, the beneficial uses for each waterbody to be protected, the WQC that protect those uses, and the water quality certification process in place to ensure standards are met. The modeling platform must enable direct comparison of model results to in-stream concentrations and allow for the analysis of the duration of those concentrations. For the watershed and receiving water loading analyses and for future implementation activities, it is also important that the modeling platform enables examination of gross land cover loading as well as in-stream concentration.

6.1.3. User Criteria

User criteria are determined by the needs, expectations, and resources of HIDOH and USEPA. Modeling software must be compatible with existing personal-computer-based hardware platforms, and due to future use for planning and permitting decisions, should be well-documented, tested, and accepted. From a resource perspective, the level of effort required to develop, calibrate, and apply the model must be commensurate with available funding, without compromising the ability to meet technical criteria. In addition to these primary criteria, the required time-frame for model development, application, and completion is important.

6.2. Model Selection and Overview

Establishing the relationship between the in-stream water quality targets and source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a number of techniques, ranging from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. The objective of this section is to present the approach taken to develop the linkage between sources and in-stream responses for TMDL development in the Hanalei Bay watershed.

Modeling the Hanalei Bay watershed presents a challenge using currently available modeling tools. The system involves various unique hydraulic features including: steep upland watersheds with adjacent lowland floodplains, sediment and nutrient settling in the estuaries, internal and external loading of nutrients and *enterococcus*, and agricultural diversions and return flows in the Hanalei River Estuary. In addition, to assist in TMDL and load target development and to provide decision support for watershed management, the model will be used to simulate various scenarios and may require future modifications to address specific management and environmental factors. Such scenarios may result from the augmentation of input data to be collected in ensuing monitoring efforts, future implementation of various management strategies or best management practices (BMPs), or adaptation and linkage to additional models developed in subsequent projects. Therefore, model flexibility is a key attribute for model selection.

The proposed modeling system was divided into two components representative of the processes essential for accurately modeling hydrology, hydrodynamics, and water quality. The first component of the modeling system was a watershed model that predicted runoff and external pollutant loading as a result of rainfall events. The second component was a hydrodynamic and water quality model that simulated the complex water circulation and pollutant transport patterns in the estuaries and Hanalei Bay (which was used as a boundary condition).

The models selected for the Hanalei Bay watershed TMDLs are components of USEPA's TMDL Modeling Toolbox (Toolbox), which has been developed through a joint effort between USEPA and Tetra Tech, Inc. (USEPA, 2003b). The Toolbox is a collection of models, modeling tools, and databases that have been utilized over the past decade in the determination of TMDLs for impaired waters. Loading Simulation Program in C++ (LSPC) is the primary watershed hydrology and pollutant loading model and the Environmental Fluids Dynamic Code (EFDC) is the receiving water hydrodynamic and water quality model in the Toolbox modeling package. A detailed description of each component of the proposed modeling system follows.

6.2.1. Watershed Model: Loading Simulation Program in C++

LSPC was selected for simulation of watershed processes, including hydrology and pollutant accumulation and wash-off, and to represent flow and water quality in the streams that drain to the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream Estuaries (Shen et al., 2004; USEPA, 2003c). LSPC integrates a geographical information system (GIS), comprehensive data storage and management capabilities, a dynamic watershed model (a recoded version of USEPA's Hydrological Simulation Program – FORTRAN [HSPF]), and a data analysis/post-processing system into a convenient PC-based windows interface that dictates no software requirements.

The LSPC model is capable of predicting water quantity and quality from complex watersheds with variable land covers, elevations, and soils. Because it is largely physically based, the model requires specific input data, such as weather, soils, land cover, and topography. This offers the ability to apply the model in areas where observation data are sparse. The model can simulate *enterococcus*, sediment, and nutrient contributions from specific source areas (e.g., subwatershed or land cover areas). This is important in terms of TMDL development and allocation analysis. Details regarding the theoretical structure of the LSPC model and its modules can be found in the HSPF User's Manual (Bicknell, et al., 2001).

6.2.2. Receiving Water Model: Environmental Fluid Dynamics Code

The Environmental Fluids Dynamic Code (EFDC) was used for the hydrodynamic and water quality modeling of the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, and Waikoko Stream Estuary. The LSPC watershed model was linked to EFDC and provided all freshwater flows and concentrations as model input. EFDC is a general purpose modeling package for simulating one- or multi-dimensional flow, transport, and bio-geochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and coastal regions. The EFDC model was originally developed by Hamrick (1992) at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software. This model is now

USEPA-supported as a component of the Toolbox, and has been used extensively to support TMDL development throughout the country. In addition to hydrodynamic, salinity, and temperature transport simulation capabilities, EFDC is capable of simulating cohesive and non-cohesive sediment transport, near field and far field discharge dilution from multiple sources, eutrophication processes, the transport and fate of toxic contaminants in the water and sediment phases, and the transport and fate of various life stages of finfish and shellfish. The EFDC model has been extensively tested, documented, and applied to environmental studies world-wide by universities, governmental agencies, and environmental consulting firms.

The structure of the EFDC model includes four major modules: (1) a hydrodynamic model, (2) a water quality model, (3) a sediment transport model, and (4) a toxics model. The EFDC hydrodynamic model is composed of six transport modules including dynamics, dye, temperature, salinity, near field plume, and a tracer module which simulates the movement of neutrally buoyant drifters released in each model cell at specified time sequences. The water quality portion of the model simulates the spatial and temporal distributions of 22 water quality parameters including dissolved oxygen, suspended algae (3 groups), attached algae, various components of carbon, nitrogen, phosphorus and silica cycles, and bacteria. These capabilities encompass the requirements of the Hanalei Bay watershed TMDL project. In this study, only the hydrodynamic and water quality sub-models were applied to simulate the water circulation and water quality interaction in Hanalei Bay and its estuaries.

6.3. *Model Application*

A complete discussion of the LSPC and EFDC models is provided in the Modeling Report, Appendix B. This document describes model configuration, hydrologic and hydrodynamic calibration and validation, and water quality calibration and validation. It also provides a list of assumptions specific to each modeling system and a discussion of model application. The models were initially calibrated to observed hydrologic and water quality data to characterize existing conditions in the watersheds and estuaries. After the models were calibrated, iterative simulations were performed by reducing the pollutant loading factors until numeric targets were achieved in the receiving waters. The loads associated with the numeric target attainment simulations were the TMDLs or load targets. Percent reductions were calculated based on the difference between the TMDLs and the loads associated with the existing conditions (calibrated model results).

7. TMDL Calculations and Allocations

This section discusses the methodology used for TMDL development and TMDL results in terms of loading capacities and required load reductions for the stream and estuary segments listed on Hawai'i's 2006 §303(d) list due to *enterococcus* and turbidity impairments (Figure 1 and
Table 3) (HIDOH, 2008). It also provides Informative TMDLs and Load Targets for the Hanalei River and Estuary, Waioli Stream and Estuary, Waipa Stream and Estuary, and Waikoko Stream and Estuary for the waterbody-pollutant combinations presented in Table 4.

7.1. Methodology

To determine load targets as well as existing loads and TMDLs for the e*nterococcus* and turbidity impaired waterbodies, two models were used: the LSPC watershed loading model and the EFDC receiving water model. The LSPC model was calibrated and validated for a five year period (May 2001 to May 2006) and the EFDC model was calibrated and validated for two overlapping years (2004 and 2005). 2005 was a high flow year (annual flow was 28 percent above the 35-year average flow) and 2004 was a fairly average flow year (annual flow was 5 percent above the 35-year average flow). Both models were run using the two year EFDC simulation period to calculate the existing and allocation loads. The year 2004 required greater load reductions than 2005; therefore, 2004 was selected as the TMDL critical year.

The *enterococcus*, TSS, and nutrients existing nonpoint source loads were estimated in the 41 modeled subbasins in the Hanalei Bay watershed using LSPC for the critical TMDL time period of 2004. The nonpoint source loads were then input to the EFDC receiving water model as lateral boundary conditions for more detailed analysis of in-stream water quality associated with the estuary fate and transport during baseline (existing) conditions. Subsequently, water quality parameters were reduced in the LSPC model and a series of simulations were performed. These results were incorporated into the EFDC model until the various water quality criteria were achieved in the estuaries (Table 5; i.e. geometric mean, 10% NTE, and 2% NTE WQC for nutrient and sediment constituents and 30-day geometric mean and single sample maximum WQC for *enterococcus*). Once these water quality criteria were reached in the estuaries, the associated loadings from the watershed were output from the model and summarized. These values are the TMDLs, Informative TMDLs, and Load Targets. The percent reductions for *enterococcus* and turbidity and the other parameters were then calculated by comparing the difference between the model results of the existing loads and the TMDLs (or Informative TMDLs or Load Targets). Load allocations were then determined by subtracting the margin of safety from the TMDL (or Informative TMDL or Load Target).

Similar analyses were performed to address the stream TMDLs, Informative TMDLs, and Load Targets. Specifically, the water quality parameters associated with existing conditions were reduced in the LSPC model until the water quality criteria were met during their associated season (Table 6; i.e. wet and dry season geometric mean, 10%

NTE, and 2% NTE WQC for nutrient and sediment constituents and 30-day geometric mean and single sample maximum WQC for *enterococcus*). The loadings associated with these model runs were output from the model and summarized to calculate the TMDLs (or load targets). The existing loads from the LSPC model were compared with these values to calculate percent reductions for the TMDLs and load targets in the freshwater segments. Load allocations were then determined by subtracting the margin of safety from the TMDL (or Informative TMDL or Load Target).

Because most of the water quality criteria in the estuary are more stringent than the stream criteria, meeting the estuary criteria will generally ensure that the stream criteria are achieved (the total nitrogen geometric mean standard is the one exception; the dry season freshwater standard is 0.180 mg/L, while the estuary standard if 0.200 mg/L). If a pollutant was listed in the estuary and the stream, the lower water quality criterion was used to ensure that the waterbody meets the most stringent criteria at all times. In addition, during the TMDL simulations, compliance with the WQC was checked at several locations in the watersheds and estuaries. For the final TMDL simulations, WQC were achieved in both the estuaries and the freshwater segments draining to those estuaries, even if the freshwater segments were not listed as impaired to ensure watershed-wide compliance; therefore, the TMDLs and load targets are conservative because they attain the most stringent WQC.

Because turbidity cannot be directly simulated using the watershed and receiving water models (Section 6.1.1.3), TSS was simulated as a surrogate. Achieving TSS TMDLs and nutrient load targets will contribute to meeting the turbidity criteria. Turbidity and TSS had a strong relationship (R^2 value of 0.7175), as described in Section 4.3.2.3, particularly at lower values; therefore, this relationship was used to convert the TSS concentrations to turbidity values for comparison with the appropriate WQC. Specifically, after model simulations were performed for TSS, these results were divided by 1.1 (using the equation presented in Figure 15) to determine the associated turbidity value. These turbidity values were then compared with the WQC to determine compliance with estuary and stream standards. It was important to evaluate both standards because there is no TSS WQC for estuaries and compliance with the streams turbidity standards was necessary to ensure attainment of the downstream estuary TMDLs. The TSS concentrations associated with the model simulation that resulted in compliance of the estuary and stream WQC for turbidity were used to calculate a TSS loading for TMDL development (i.e. TSS TMDLs were used as a surrogate for turbidity, although compliance was determined by comparing to the applicable turbidity WQC).

7.2. TMDL Calculation

The TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody while still achieving the numeric targets. In TMDL development, allowable loadings from pollutant sources that cumulatively amount to no more than the TMDL must be established; this provides the basis to establish water quality-based controls. TMDLs can be expressed on a mass loading basis (e.g., number of bacteria per year) or as a concentration in accordance with 40 CFR 130.2(l).

A TMDL for a given pollutant and waterbody is comprised of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality in the receiving waterbody. Conceptually, this definition is represented by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

TMDLs were established for each segment identified in Table 2 using the methodology described above, while similarly calculated Informative TMDLs and Load Targets were determined for each waterbody-pollutant combinations in Table 4. These calculations identify and allocate appropriate loadings to the subwatersheds that cause or contribute to the impairment. The WLA portion of this equation is the total loading assigned to point sources. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and computational methodology, as described in Section 7.2.3. An implicit MOS was used for this TMDL.

7.2.1. Waste Load Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source discharge regulated under a discharge permit. However, no MS4 or other individual NPDES permits for point sources have been issued in the Hanalei Bay watershed. If WLAs are required to accommodate future point source discharges, then the LAs will be revised and the overall changes in TMDL allocations will be submitted to USEPA for approval.

7.2.2. Load Allocations

According to federal regulations (40 CFR 130.2(g)), load allocations are best estimates of the nonpoint source or background loading. This nonpoint source runoff addresses all loadings that are not regulated by a discharge permit (which are allocated as WLAs). Because there are no WLAs in the Hanalei Bay watershed, this report only provides LAs associated with the *enterococcus* and turbidity TMDLs.

7.2.3. Margin of Safety

The statute and regulations require that a TMDL include a margin of safety (MOS) to account for any uncertainty in the data and the computational methodology used for TMDL analysis. There are two ways to incorporate the MOS (USEPA, 1991): (1) implicitly incorporate the MOS using conservative model assumptions to develop allocations and (2) explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations. The TMDLs for the Hanalei Bay watershed included both an explicit and implicit MOS. The explicit MOS was computed as 5 percent of the calculated TMDL value. The implicit MOS was incorporated through the use of conservative assumptions during the TMDL development process. Specifically, the benthic nutrient fluxes for nitrogen and phosphorus were kept constant for both the existing and TMDL conditions. It is likely, however, that these fluxes will be reduced under TMDL conditions due to the reduction in source nutrient contributions.

7.3. TMDL Results and Allocations

The LSPC and EFDC models for were run for 2004 for the baseline (existing) conditions. The TMDL allocations and other allocation applications were then determined by performing a series of simulations that involved reducing the watershed loads of bacteria, sediment, and nutrients until each of the numeric targets described in Section 3 were achieved (i.e. geometric mean, 10% NTE, and 2% NTE WQC for nutrient and sediment constituents [while considering different wet and dry season WQC in streams] and 30-day geometric mean and single sample maximum WQC for *enterococcus*). Associated loads were then determined for each of these targets. While only the stream standards vary by storm season, estuary TMDL results are based on achieving the year-round estuary standards. The annual load results are presented seasonally to maintain consistency with the stream TMDLs and for implementation purposes. In the allocation scenarios, contributions from all land covers were reduced uniformly to obtain general watershed-wide reductions (i.e. all land covers had the same percent reduction). Additional scenarios can also be performed that can vary the relative land cover contributions for each parameter and would be further enhanced with additional modeling that better identified and quantified sources.

The baseline and allocation TSS and *enterococcus* loads associated with each WQC for the §303(d) listed impaired waterbodies (
Table 3 and Figure 1) during the wet season and dry season are presented in Table 14 and Table 15, respectively. As noted previously, the TSS TMDLs are a surrogate for turbidity. These tables also present the reductions necessary to meet the TMDLs (presented as both mass and percent). Model results indicate that for TSS the load reductions from baseline range from 77.0 to 97.8 percent to achieve the geometric mean WQC, 64.3 to 96.3 percent to achieve the 10% NTE WQC, and 53.5 to 94.0 percent to achieve the 2% NTE WQC , depending on the waterbody. In the Hanalei River Estuary, a 35 percent reduction from baseline load is necessary to achieve the 30-day running geometric mean WQC for *enterococcus*, while a 99.4 percent reduction is necessary to meet the single sample maximum WQC.

Informative TMDLs, Load Targets, and suggested reductions (in mass and percent) for the waterbody-pollutant combinations listed in Table 4 are presented in Table 16 through Table 25. Specifically, Table 16 presents the wet and dry season values for TSS and Table 17 presents the same information for *enterococcus*. Wet and dry season allocations and suggested reductions for nutrients are presented in Table 18 through Table 25. The suggested percent reductions for nutrients are identical to the TSS values in the same watershed because implementation strategies expected to reduce sediment and nutrients are assumed to be the similar, especially since sediment was found to be correlated to total nitrogen and total phosphorous. Ammonia and nitrite plus nitrate were not correlated with TSS; however, management strategies that address total nitrogen and total phosphorous are likely to also reduce other nutrients, thus these parameters were reduced similarly in the model runs used to determine the Informative TMDLs and Load Targets.

7.4. Critical Conditions and Seasonal Variation

TMDLs are required to consider critical conditions and seasonal variation for streamflow, loading, and water quality parameters. The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of WQC for all other conditions. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable. In the Hanalei Bay watershed, the critical conditions for *enterococcus* and turbidity impairments coincide with storm events. The Data Analysis section (Section 4) illustrates that such events can occur throughout the year.

A long-term continuous simulation is the one way to determine when the pollutants are above the target endpoints; therefore, models were run for a two year period (2004 and 2005). The more critical of the two years simulated (i.e. the year that required the greatest percent reductions) was 2004, which is characterized by both low flows during the dry season and high-flow events during storms (wet and dry seasons). This year was used for TMDL analyses to ensure that the WQC are attained during the most critical conditions.

Through simulation of an entire critical year, daily concentrations were estimated for all seasons of that year and compared to the numeric targets to determine necessary reductions. Model simulation of a full year accounted for seasonal variations in rainfall, evaporation, and associated impacts on runoff and transport of bacteria and sediment loads to receiving waters. Although large storms in the wet season (November to April) of the critical year were associated with large volumes of runoff that transported large loads, storms during the dry season (May to October) also provided large loads. To consider the variability among seasons and ensure the greatest protection of the receiving waters, the TMDLs were calculated so wet and dry WQC, where applicable, were attained during the appropriate season and the additional year-round WQC were attained throughout the year.

Table 14. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs (Note: key to table continues on following page)

Total Suspended Solids						
Wet Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1431.3	75.3	1506.6	6550.7	5044.0	77.0%
Hanalei River Estuary	1520.6	80.0	1600.6	6959.2	5358.6	77.0%
Waioli Stream Estuary	117.5	6.2	123.7	1124.9	1001.1	89.0%
Waipa Stream	49.5	2.6	52.1	452.8	400.7	88.5%
Waipa Stream Estuary	53.7	2.8	56.5	491.6	435.1	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	110.8	108.4	97.8%
Wet Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2220.0	116.8	2336.8	6550.7	4213.9	64.3%
Hanalei River Estuary	2358.4	124.1	2482.5	6959.2	4476.7	64.3%
Waioli Stream Estuary	187.5	9.9	197.4	1124.9	927.4	82.5%
Waipa Stream	63.3	3.330	66.6	452.8	386.2	85.3%
Waipa Stream Estuary	68.7	3.6	72.3	491.6	419.3	85.3%
Waikoko Stream Estuary	3.9	0.2	4.1	110.8	106.7	96.3%
Wet Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2894.1	152.3	3046.4	6550.7	3504.3	53.5%
Hanalei River Estuary	3074.5	161.8	3236.4	6959.2	3722.9	53.5%
Waioli Stream Estuary	318.2	16.8	334.9	1124.9	789.9	70.2%
Waipa Stream	59.8	3.147	62.9	452.8	389.8	86.1%
Waipa Stream Estuary	64.9	3.4	68.3	491.6	423.3	86.1%
Waikoko Stream Estuary	6.3	0.3	6.7	110.8	104.1	94.0%
Dry Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1415.8	74.5	1490.3	6479.5	4989.2	77.0%
Hanalei River Estuary	1504.1	79.2	1583.2	6883.6	5300.4	77.0%
Waioli Stream Estuary	116.3	6.1	122.4	1112.6	990.2	89.0%
Waipa Stream	48.9	2.6	51.5	447.9	396.4	88.5%
Waipa Stream Estuary	53.1	2.8	55.9	486.3	430.4	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	109.6	107.2	97.8%
Dry Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2195.8	115.6	2311.4	6479.5	4168.1	64.3%
Hanalei River Estuary	2332.8	122.8	2455.6	6883.6	4428.0	64.3%
Waioli Stream Estuary	185.5	9.8	195.3	1112.6	917.4	82.5%
Waipa Stream	62.6	3.294	65.9	447.9	382.0	85.3%
Waipa Stream Estuary	67.9	3.6	71.5	486.3	414.7	85.3%
Waikoko Stream Estuary	3.8	0.2	4.0	109.6	105.6	96.3%
Dry Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2862.6	150.7	3013.3	6479.5	3466.2	53.5%
Hanalei River Estuary	3041.1	160.1	3201.2	6883.6	3682.4	53.5%
Waioli Stream Estuary	314.7	16.6	331.3	1112.6	781.3	70.2%
Waipa Stream	59.2	3.113	62.3	447.9	385.6	86.1%
Waipa Stream Estuary	64.2	3.4	67.6	486.3	418.7	86.1%
Waikoko Stream Estuary	6.3	0.3	6.6	109.6	103.0	94.0%

Note: TMDL allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; kgd = kilograms per day

Table 15. *Enterococcus* TMDL Load Allocations and Load Reductions Required to Achieve TMDLs

Enterococcus						
Wet Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.6E+12	7.0E+12	2.5E+12	35.0%
Hanalei River Estuary	4.9E+12	2.6E+11	5.1E+12	7.9E+12	2.8E+12	35.0%
Wet Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.6E+10	7.0E+12	7.0E+12	99.4%
Hanalei River Estuary	4.9E+10	2.6E+09	5.1E+10	7.9E+12	7.8E+12	99.4%
Dry Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.5E+12	7.0E+12	2.4E+12	35.0%
Hanalei River Estuary	4.8E+12	2.5E+11	5.1E+12	7.8E+12	2.7E+12	35.0%
Dry Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.5E+10	7.0E+12	6.9E+12	99.4%
Hanalei River Estuary	4.8E+10	2.5E+09	5.1E+10	7.8E+12	7.8E+12	99.4%

Note: TMDL allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (generally, the highest 10% of flows)
Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; #/day = number per day

Table 16. Total Suspended Solids Informative TMDLs and Suggested Reductions

Total Suspended Solids						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	112.2	5.9	118.1	1073.9	955.8	89.0%
Waikoko Stream	2.2	0.1	2.3	106.4	104.1	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	179.0	9.423	188.5	1073.9	885.4	82.5%
Waikoko Stream	3.7	0.196	3.9	106.4	102.5	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	303.8	15.988	319.8	1073.9	754.2	70.2%
Waikoko Stream	6.1	0.320	6.4	106.4	100.0	94.0%
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	111.0	5.8	116.8	1062.2	945.4	89.0%
Waikoko Stream	2.2	0.1	2.3	105.2	102.9	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	177.1	9.321	186.4	1062.2	875.8	82.5%
Waikoko Stream	3.7	0.194	3.9	105.2	101.4	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	300.5	15.814	316.3	1062.2	746.0	70.2%
Waikoko Stream	6.0	0.317	6.3	105.2	98.9	94.0%

Note: Informative TMDLS and load allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 17. *Enterococcus* Informative TMDLs and Suggested Reductions

Enterococcus						
Wet Season Baseflow* (Geometric Mean)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	8.5E+11	4.5E+10	9.0E+11	1.8E+12	8.6E+11	49.0%
Waioli Stream	8.1E+11	4.3E+10	8.5E+11	1.7E+12	8.2E+11	49.0%
Waipa Stream Estuary	6.2E+11	3.3E+10	6.5E+11	8.3E+11	1.7E+11	21.0%
Waipa Stream	5.7E+11	3.0E+10	6.0E+11	7.6E+11	1.6E+11	21.0%
Waikoko Stream Estuary	8.9E+10	4.7E+09	9.4E+10	2.6E+11	1.7E+11	64.0%
Waikoko Stream	8.7E+10	4.6E+09	9.1E+10	2.5E+11	1.6E+11	64.0%
Wet Season Runoff* (Single Sample Maximum)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	1.0E+10	5.5E+08	1.1E+10	1.8E+12	1.7E+12	99.4%
Waioli Stream	9.9E+09	5.2E+08	1.0E+10	1.7E+12	1.7E+12	99.4%
Waipa Stream Estuary	4.6E+09	2.4E+08	4.9E+09	8.3E+11	8.2E+11	99.4%
Waipa Stream	4.3E+09	2.2E+08	4.5E+09	7.6E+11	7.6E+11	99.4%
Waikoko Stream Estuary	8.7E+08	4.6E+07	9.1E+08	2.6E+11	2.6E+11	99.7%
Waikoko Stream	8.4E+08	4.4E+07	8.9E+08	2.5E+11	2.5E+11	99.7%
Dry Season Baseflow* (Geometric Mean)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	8.4E+11	4.4E+10	8.9E+11	1.7E+12	8.5E+11	49.0%
Waioli Stream	8.0E+11	4.2E+10	8.5E+11	1.7E+12	8.1E+11	49.0%
Waipa Stream Estuary	6.1E+11	3.2E+10	6.5E+11	8.2E+11	1.7E+11	21.0%
Waipa Stream	5.7E+11	3.0E+10	6.0E+11	7.5E+11	1.6E+11	21.0%
Waikoko Stream Estuary	8.8E+10	4.6E+09	9.3E+10	2.6E+11	1.6E+11	64.0%
Waikoko Stream	8.6E+10	4.5E+09	9.0E+10	2.5E+11	1.6E+11	64.0%
Dry Season Runoff* (Single Sample Maximum)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	1.0E+10	5.4E+08	1.1E+10	1.7E+12	1.7E+12	99.4%
Waioli Stream	9.8E+09	5.1E+08	1.0E+10	1.7E+12	1.6E+12	99.4%
Waipa Stream Estuary	4.6E+09	2.4E+08	4.8E+09	8.2E+11	8.1E+11	99.4%
Waipa Stream	4.2E+09	2.2E+08	4.4E+09	7.5E+11	7.5E+11	99.4%
Waikoko Stream Estuary	8.6E+08	4.5E+07	9.0E+08	2.6E+11	2.6E+11	99.7%
Waikoko Stream	8.3E+08	4.4E+07	8.8E+08	2.5E+11	2.5E+11	99.7%

Note: Load Targets and allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and

(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (generally, the highest 10% of flows)

Acronyms: MOS = Margin of Safety; #/day = number per day

Table 18. Wet Season Ammonia Informative TMDLs and Load Targets and Suggested Reductions

Ammonia						
Wet Season Baseflow*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	9.1	0.481	9.6	41.8	32.2	77.0%
Hanalei River	*4.4*	*0.233*	*4.7*	*20.2*	*15.6*	*77.0%*
Waioli Stream Estuary	1.5	0.077	1.5	14.1	12.5	89.0%
Waioli Stream	*1.0*	*0.052*	*1.0*	*9.4*	*8.4*	*89.0%*
Waipa Stream Estuary	0.5	0.025	0.5	4.4	3.9	88.5%
Waipa Stream	*0.1*	*0.007*	*0.1*	*1.3*	*1.1*	*88.5%*
Waikoko Stream Estuary	0.1	0.008	0.2	7.1	6.9	97.8%
Waikoko Stream	0.1	0.007	0.1	6.5	6.4	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	14.2	0.745	14.9	41.8	26.9	64.3%
Hanalei River	*6.9*	*0.361*	*7.2*	*20.2*	*13.0*	*64.3%*
Waioli Stream Estuary	2.3	0.123	2.5	14.1	11.6	82.4%
Waioli Stream	*1.6*	*0.083*	*1.7*	*9.4*	*7.8*	*82.4%*
Waipa Stream Estuary	0.6	0.032	0.6	4.4	3.7	85.3%
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*85.3%*
Waikoko Stream Estuary	0.2	0.013	0.3	7.1	6.8	96.3%
Waikoko Stream	0.2	0.012	0.2	6.5	6.3	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	18.5	0.972	19.4	41.8	22.4	53.5%
Hanalei River	*8.9*	*0.471*	*9.4*	*20.2*	*10.8*	*53.5%*
Waioli Stream Estuary	4.0	0.209	4.2	14.1	9.9	70.2%
Waioli Stream	*2.7*	*0.140*	*2.8*	*9.4*	*6.6*	*70.2%*
Waipa Stream Estuary	0.6	0.030	0.6	4.4	3.8	86.1%
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*86.1%*
Waikoko Stream Estuary	0.4	0.021	0.4	7.1	6.7	94.0%
Waikoko Stream	*0.4*	*0.020*	*0.4*	*6.5*	*6.1*	*94.0%*

Note: Informative TMDLs, Load Allocations, and Load Targets in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and

(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 19. Dry Season Ammonia Informative TMDLs and Load Targets and Suggested Reductions

Ammonia						
Dry Season Baseflow*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	9.0	0.475	9.5	41.3	31.8	77.0%
Hanalei River	*4.4*	*0.230*	*4.6*	*20.0*	*15.4*	*77.0%*
Waioli Stream Estuary	1.5	0.077	1.5	13.9	12.4	89.0%
Waioli Stream	*1.0*	*0.051*	*1.0*	*9.3*	*8.3*	*89.0%*
Waipa Stream Estuary	0.5	0.025	0.5	4.3	3.8	88.5%
Waipa Stream	*0.1*	*0.007*	*0.1*	*1.3*	*1.1*	*88.5%*
Waikoko Stream Estuary	0.1	0.008	0.2	7.0	6.9	97.8%
Waikoko Stream	*0.1*	*0.007*	*0.1*	*6.5*	*6.3*	*97.8%*
Dry Season 10% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	14.0	0.737	14.7	41.3	26.6	64.3%
Hanalei River	*6.8*	*0.357*	*7.1*	*20.0*	*12.9*	*64.3%*
Waioli Stream Estuary	2.3	0.122	2.4	13.9	11.5	2.3
Waioli Stream	*1.6*	*0.082*	*1.6*	*9.3*	*7.7*	*1.6*
Waipa Stream Estuary	0.6	0.032	0.6	4.3	3.7	0.6
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*0.2*
Waikoko Stream Estuary	0.2	0.013	0.3	7.0	6.8	0.2
Waikoko Stream	*0.2*	*0.012*	*0.2*	*6.5*	*6.2*	*0.2*
Dry Season 2% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	18.3	0.961	19.2	41.3	22.1	53.5%
Hanalei River	*8.8*	*0.466*	*9.3*	*20.0*	*10.7*	*53.5%*
Waioli Stream Estuary	3.9	0.207	4.1	13.9	9.8	70.2%
Waioli Stream	*2.6*	*0.139*	*2.8*	*9.3*	*6.5*	*70.2%*
Waipa Stream Estuary	0.6	0.030	0.6	4.3	3.7	86.1%
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*86.1%*
Waikoko Stream Estuary	0.4	0.021	0.4	7.0	6.6	94.0%
Waikoko Stream	*0.4*	*0.019*	*0.4*	*6.5*	*6.1*	*94.0%*

Note: : Informative TMDLs, Load Allocations, and Load Targets in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 20. Wet Season Nitrite Plus Nitrate Informative TMDLs and Suggested Reductions

Nitrite plus Nitrate						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	10.3	0.541	10.8	47.0	36.2	77.0%
Hanalei River	8.2	0.432	8.6	37.6	28.9	77.0%
Waioli Stream Estuary	1.1	0.059	1.2	10.8	9.6	89.0%
Waioli Stream	0.9	0.050	1.0	9.0	8.0	89.0%
Waipa Stream Estuary	0.4	0.024	0.5	4.1	3.6	88.5%
Waipa Stream	0.3	0.017	0.3	3.0	2.6	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	3.0	2.9	97.8%
Waikoko Stream	0.1	0.003	0.1	2.8	2.7	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	15.9	0.839	16.8	47.0	30.3	64.3%
Hanalei River	12.7	0.670	13.4	37.6	24.2	64.3%
Waioli Stream Estuary	1.8	0.094	1.9	10.8	8.9	82.4%
Waioli Stream	1.5	0.079	1.6	9.0	7.5	82.4%
Waipa Stream Estuary	0.6	0.030	0.6	4.1	3.5	85.3%
Waipa Stream	0.4	0.022	0.4	3.0	2.5	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	3.0	2.9	96.3%
Waikoko Stream	0.1	0.005	0.1	2.8	2.7	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	20.8	1.093	21.9	47.0	25.2	53.5%
Hanalei River	16.6	0.874	17.5	37.6	20.1	53.5%
Waioli Stream Estuary	3.0	0.160	3.2	10.8	7.6	70.2%
Waioli Stream	2.6	0.135	2.7	9.0	6.3	70.2%
Waipa Stream Estuary	0.5	0.028	0.6	4.1	3.5	86.1%
Waipa Stream	0.4	0.021	0.4	3.0	2.5	86.1%
Waikoko Stream Estuary	0.2	0.009	0.2	3.0	2.8	94.0%
Waikoko Stream	0.2	0.008	0.2	2.8	2.6	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 21. Dry Season Nitrite Plus Nitrate Informative TMDLs and Suggested Reductions

Nitrite plus Nitrate						
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	10.2	0.535	10.7	46.5	35.8	77.0%
Hanalei River	8.1	0.428	8.6	37.2	28.6	77.0%
Waioli Stream Estuary	1.1	0.059	1.2	10.6	9.5	89.0%
Waioli Stream	0.9	0.049	1.0	8.9	8.0	89.0%
Waipa Stream Estuary	0.4	0.023	0.5	4.0	3.6	88.5%
Waipa Stream	0.3	0.017	0.3	2.9	2.6	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	3.0	2.9	97.8%
Waikoko Stream	0.1	0.003	0.1	2.8	2.7	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	15.8	0.829	16.6	46.5	29.9	64.3%
Hanalei River	12.6	0.663	13.3	37.2	23.9	64.3%
Waioli Stream Estuary	1.8	0.093	1.9	10.6	8.8	82.4%
Waioli Stream	1.5	0.078	1.6	8.9	7.4	82.4%
Waipa Stream Estuary	0.6	0.030	0.6	4.0	3.4	85.3%
Waipa Stream	0.4	0.021	0.4	2.9	2.5	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	3.0	2.9	96.3%
Waikoko Stream	0.1	0.005	0.1	2.8	2.7	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	20.5	1.082	21.6	46.5	24.9	53.5%
Hanalei River	16.4	0.864	17.3	37.2	19.9	53.5%
Waioli Stream Estuary	3.0	0.158	3.2	10.6	7.5	70.2%
Waioli Stream	2.5	0.133	2.7	8.9	6.3	70.2%
Waipa Stream Estuary	0.5	0.028	0.6	4.0	3.5	86.1%
Waipa Stream	0.4	0.020	0.4	2.9	2.5	86.1%
Waikoko Stream Estuary	0.2	0.009	0.2	3.0	2.8	94.0%
Waikoko Stream	0.2	0.008	0.2	2.8	2.6	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 22. Wet Season Total Nitrogen Informative TMDLs and Suggested Reductions

Total Nitrogen						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	80.3	4.225	84.5	367.4	282.9	77.0%
Hanalei River	69.0	3.630	72.6	315.7	243.1	77.0%
Waioli Stream Estuary	8.0	0.423	8.5	77.0	68.5	89.0%
Waioli Stream	7.1	0.373	7.5	67.8	60.3	89.0%
Waipa Stream Estuary	3.3	0.173	3.5	30.0	26.6	88.5%
Waipa Stream	2.6	0.135	2.7	23.4	20.7	88.5%
Waikoko Stream Estuary	0.3	0.018	0.4	16.7	16.3	97.8%
Waikoko Stream	0.3	0.017	0.3	15.6	15.3	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	124.5	6.552	131.0	367.4	236.4	64.3%
Hanalei River	107.0	5.629	112.6	315.7	203.1	64.3%
Waioli Stream Estuary	12.8	0.676	13.5	77.0	63.5	82.4%
Waioli Stream	11.3	0.595	11.9	67.8	55.9	82.4%
Waipa Stream Estuary	4.2	0.221	4.4	30.0	25.6	85.3%
Waipa Stream	3.3	0.172	3.4	23.4	20.0	85.3%
Waikoko Stream Estuary	0.6	0.031	0.6	16.7	16.0	96.3%
Waikoko Stream	0.5	0.029	0.6	15.6	15.0	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	162.3	8.543	170.9	367.4	196.6	53.5%
Hanalei River	139.5	7.340	146.8	315.7	168.9	53.5%
Waioli Stream Estuary	21.8	1.147	22.9	77.0	54.1	70.2%
Waioli Stream	19.2	1.009	20.2	67.8	47.6	70.2%
Waipa Stream Estuary	4.0	0.209	4.2	30.0	25.9	86.1%
Waipa Stream	3.1	0.163	3.3	23.4	20.2	86.1%
Waikoko Stream Estuary	1.0	0.050	1.0	16.7	15.7	94.0%
Waikoko Stream	0.9	0.047	0.9	15.6	14.7	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 23. Dry Season Total Nitrogen Informative TMDLs and Suggested Reductions

Total Nitrogen						
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	79.4	4.179	83.6	363.4	279.8	77.0%
Hanalei River	68.2	3.591	71.8	312.2	240.4	77.0%
Waioli Stream Estuary	8.0	0.419	8.4	76.2	67.8	89.0%
Waioli Stream	7.0	0.369	7.4	67.0	59.7	89.0%
Waipa Stream Estuary	3.2	0.171	3.4	29.7	26.3	88.5%
Waipa Stream	2.5	0.133	2.7	23.2	20.5	88.5%
Waikoko Stream Estuary	0.3	0.018	0.4	16.5	16.1	97.8%
Waikoko Stream	0.3	0.017	0.3	15.4	15.1	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	123.1	6.481	129.6	363.4	233.8	64.3%
Hanalei River	105.8	5.568	111.4	312.2	200.9	64.3%
Waioli Stream Estuary	12.7	0.669	13.4	76.2	62.8	82.4%
Waioli Stream	11.2	0.588	11.8	67.0	55.3	82.4%
Waipa Stream Estuary	4.2	0.218	4.4	29.7	25.3	85.3%
Waipa Stream	3.2	0.170	3.4	23.2	19.8	85.3%
Waikoko Stream Estuary	0.6	0.030	0.6	16.5	15.9	96.3%
Waikoko Stream	0.5	0.028	0.6	15.4	14.9	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	160.5	8.450	169.0	363.4	194.4	53.5%
Hanalei River	137.9	7.260	145.2	312.2	167.0	53.5%
Waioli Stream Estuary	21.5	1.134	22.7	76.2	53.5	70.2%
Waioli Stream	19.0	0.998	20.0	67.0	47.1	70.2%
Waipa Stream Estuary	3.9	0.206	4.1	29.7	25.6	86.1%
Waipa Stream	3.1	0.161	3.2	23.2	19.9	86.1%
Waikoko Stream Estuary	0.9	0.050	1.0	16.5	15.5	94.0%
Waikoko Stream	0.9	0.047	0.9	15.4	14.5	94.0%

Note: informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 24. Wet Season Total Phosphorous Informative TMDLs and Suggested Reductions

Total Phosphorous						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	19.2	1.012	20.2	88.0	67.7	77.0%
Hanalei River	17.4	0.915	18.3	79.5	61.3	77.0%
Waioli Stream Estuary	1.9	0.098	2.0	17.8	15.8	89.0%
Waioli Stream	1.7	0.090	1.8	16.4	14.6	89.0%
Waipa Stream Estuary	0.8	0.041	0.8	7.1	6.3	88.5%
Waipa Stream	0.7	0.035	0.7	6.1	5.4	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	2.8	2.7	97.8%
Waikoko Stream	0.1	0.003	0.1	2.6	2.6	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	29.8	1.569	31.4	88.0	56.6	64.3%
Hanalei River	27.0	1.419	28.4	79.5	51.2	64.3%
Waioli Stream Estuary	3.0	0.156	3.1	17.8	14.6	82.4%
Waioli Stream	2.7	0.144	2.9	16.4	13.5	82.4%
Waipa Stream Estuary	1.0	0.052	1.0	7.1	6.1	85.3%
Waipa Stream	0.8	0.045	0.9	6.1	5.2	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	2.8	2.7	96.3%
Waikoko Stream	0.1	0.005	0.1	2.6	2.5	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	38.9	2.045	40.9	88.0	47.1	53.5%
Hanalei River	35.1	1.850	37.0	79.5	42.6	53.5%
Waioli Stream Estuary	5.0	0.264	5.3	17.8	12.5	70.2%
Waioli Stream	4.6	0.244	4.9	16.4	11.5	70.2%
Waipa Stream Estuary	0.9	0.049	1.0	7.1	6.1	86.1%
Waipa Stream	0.8	0.042	0.8	6.1	5.2	86.1%
Waikoko Stream Estuary	0.2	0.008	0.2	2.8	2.6	94.0%
Waikoko Stream	0.2	0.008	0.2	2.6	2.5	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 25. Dry Season Total Phosphorous Informative TMDLs and Suggested Reductions

Total Phosphorous						
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	19.0	1.001	20.0	87.0	67.0	77.0%
Hanalei River	19.0	1.001	20.0	87.0	67.0	77.0%
Waioli Stream Estuary	1.8	0.097	1.9	17.6	15.6	89.0%
Waioli Stream	1.7	0.089	1.8	16.2	14.4	89.0%
Waipa Stream Estuary	0.8	0.040	0.8	7.0	6.2	88.5%
Waipa Stream	0.7	0.034	0.7	6.0	5.3	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	2.7	2.7	97.8%
Waikoko Stream	0.1	0.003	0.1	2.6	2.5	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	29.5	1.552	31.0	87.0	56.0	64.3%
Hanalei River	26.7	1.403	28.1	78.7	50.6	64.3%
Waioli Stream Estuary	2.9	0.154	3.1	17.6	14.5	82.4%
Waioli Stream	2.7	0.142	2.8	16.2	13.3	82.4%
Waipa Stream Estuary	1.0	0.052	1.0	7.0	6.0	85.3%
Waipa Stream	0.8	0.044	0.9	6.0	5.1	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	2.7	2.6	96.3%
Waikoko Stream	0.1	0.005	0.1	2.6	2.5	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	38.4	2.023	40.5	87.0	46.5	53.5%
Hanalei River	34.8	1.829	36.6	78.7	42.1	53.5%
Waioli Stream Estuary	5.0	0.261	5.2	17.6	12.3	70.2%
Waioli Stream	4.6	0.241	4.8	16.2	11.4	70.2%
Waipa Stream Estuary	0.9	0.049	1.0	7.0	6.1	86.1%
Waipa Stream	0.8	0.042	0.8	6.0	5.2	86.1%
Waikoko Stream Estuary	0.2	0.008	0.2	2.7	2.6	94.0%
Waikoko Stream	0.1	0.008	0.2	2.6	2.4	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram or number; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs, Existing Loads** and **Reductions Required** may actually be greater than 0.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: MOS = Margin of Safety; kgd = kilograms per day

8. Implementation Framework for Phased TMDL Approach

The TMDL process provides a technical basis for activities that reduce pollutant loads, improve water quality, and repair the integrity of aquatic ecosystems. These activities are more likely to be funded by certain federal programs when they are supported by a detailed planning document such as a TMDL Implementation Plan or a Watershed Based Plan. The TMDL implementation framework presented here is a starting point for this type of detailed planning effort. It provides general prescriptions for watershed health and explains how key results from TMDL development suggest where to focus implementation activities and how to complete them. Additional suggestions about specific activities (what, where, why, how, when, by whom, at what cost, and with what funding sources?) and their relative feasibility, benefits, and priorities will hopefully be generated during the upcoming development of a Watershed Based Plan for Hanalei.

Due to the difficulty of drawing precise links between nonpoint sources (including natural background, endangered waterbirds, wildlife, livestock, and wetland farming) and waterbody impairment in the Hanalei Bay Watershed, we propose employing a phased approach to the development and implementation of these TMDL load allocations. This phased approach allows us to use available information to establish interim targets, begin to implement needed controls and restoration activities, monitor waterbody response to these actions, and plan for TMDL review and revision in the future, including further assessment of how realistic or unrealistic the load reductions required may be. Thus, this TMDL decision is a starting point for nonpoint source implementation activities that can be adapted as new information becomes available, and that are intended to include ongoing review and future revision of the TMDL decision.

Numerous public comments received about the draft TMDL expressed concerns about the feasibility of TMDL implementation given the seemingly extreme load reductions required and the accompanying threat of potentially damaging implementation mandates, costs, and societal impacts. These concerns seem to be best addressed on the context of ongoing phased TMDL development, watershed based planning, and other DOH water pollution control and water quality management program activities in Hanalei. Therefore, this TMDL implementation framework and the upcoming Watershed Based Plan are intended to inform and guide, not mandate, the manner in which the watershed community chooses to achieve load reductions, meet water quality standards, manage costs, minimize negative societal impacts, and maximize environmental effectiveness. While highlighting some of the more important, potentially fruitful, or oppressive choices for this effort, DOH advocates a community-based adaptive approach to implementing nonpoint source load allocations (based on TMDL decisions, other watershed planning results, and local knowledge and experience) that prevents and reduces nonpoint source pollution while balancing health, environmental, economic and social concerns.

Providing more information and explanation concerning the scientific basis of the load reductions, and other aspects of the TMDL process, is an important objective of the upcoming TMDL development phases. In accordance with the selection of Hanalei by DOH and EPA as one of three areas in the state where water quality improvements may be possible and multiple clean water program tools may be applied to help make these improvements, DOH will have to spend more time and effort reaching out to the Hanalei community, Hawaii's Implementation Plan for Polluted Runoff Control (Coastal Zone Management Program and Polluted Runoff Control Program, 2000) and Hawaii's Coastal Nonpoint Pollution Control Program (Hawaii Coastal Zone Management Program, 1996) establish a foundation for voluntary and regulatory approaches to improving and maintaining watershed health. Both these plans are being updated and revised to better address, among other objectives, implementation of TMDL allocations. Specific implementation measures for the Hanalei watershed may be imported or adapted from a number of existing and pending planning documents, including:

Dong, Dacheng et al. 2002. Building Collaboration: Toward Co-management for the Hanalei Ahupua'a, Kaua'i, Hawai'i – Planning Practicum Fall 2002. University of Hawaii at Manoa, Department of Urban and Regional Planning.

Hanalei Watershed Hui. 2006. Final Report to U.S. Environmental Protection Agency – Hanalei Targeted Watershed Initiative Grant.

Hanalei Watershed Hui. nd. Hanalei Watershed Hui Watershed Action Plan.
www.hanaleiwatershedhui.org/wap.htm

Hanalei Watershed Hui Program. 2005. Environmental Protection Agency's Watershed Initiative Grant – Project Update.
www.hanaleiwatershedhui.org/science/research/WIG.pdf.pdf

Kauai Watershed Alliance. 2005. Management Plan.

State of Hawaii Department of Education. Site-specific Storm Water Management Program Plans for NPDES Phase 2 MS4 facilities.

State of Hawaii Department of Land and Natural Resources. Halelea Forest Reserve forest resource management plans and conservation district use permits/plans.

State of Hawaii Department of Transportation, Highways Division. Storm Water Management Plans for NPDES Phase 1 MS4 permit (Oahu).

U.S. Environmental Protection Agency et al. 2004. Hawaii's Local Action Strategy to Address Land-Based Pollution Threats to Coral Reefs.
www.hawaii.gov/health/environmental/water/cleanwater/prc/pdf/LAS.CR-LBP_fnl_3-22-04.pdf

U.S. Fish and Wildlife Service. Hanalei Refuge Management Plan.

Various. Site-specific Storm Water Management Program Plans for NPDES Phase 2 MS4 facilities (Oahu).

Various. Soil and Water Conservation Plans, Comprehensive Nutrient Management Plans, and other Farm Bill Program plans for agricultural lands, and other public and private planning initiatives (see ***Land ownership*** and ***Regulatory and management authority*** below).

By using these general approaches and specific measures, incorporating the LAs and implementation framework from the TMDLs, and/or conducting the actions prescribed by a Watershed Based Plan, an implementation project can potentially access additional Clean Water Act §319(h) incremental funds for water quality improvement projects. Such projects may also qualify for construction funding from the DOH Clean Water State Revolving Fund Program. Questions of where to focus project activities and how to complete them can be addressed by viewing the watershed from various perspectives - such as regulatory-based (waterbody classes and uses), property-based (land ownership), management-based (regulatory and management authority), problem-based (land cover and degrading activities), and solution-based (implementation tools, technical/financial assistance, and previous/ongoing efforts) – each of which is discussed below. Other resources for these efforts include:

> Nonpoint Source Control Branch. 2005. EPA Handbook for developing watershed plans to restore and protect our waters (Draft). U.S. Environmental Protection Agency Office of Water.
> www.epa.gov/nps/watershed_handbook, and other EPA publications at www.epa.gov/owow/nps/pubs.html
>
> Center for Watershed Protection. Various resources at www.cwp.org.

8.1. Waterbody classes and uses

The TMDL process provides strategies for achieving and maintaining water quality standards. A water quality standard consists of the designated use(s) for the water, water quality criteria designed to protect the use(s), and an antidegradation policy. The Clean Water Act also demands that existing uses (as of November 28, 1975) be protected. Thus the TMDL Implementation Framework incorporates these uses, criteria, and policy as organizing concepts for identifying specific implementation activities and approaches.

For example, Hanalei Bay is a Class AA marine waterbody (embayment) that is to receive "an absolute minimum of pollution or alteration of water quality from any human-caused source or actions," and its designated uses include "conservation of coral reefs and wilderness areas ... and aesthetic enjoyment." Thus the relative importance of an inland waterbody segment's impact upon embayment pollution minimization, water quality alteration, coral reefs, and aesthetic enjoyment could be factors for prioritizing implementation activities that affect inland waters (streams and estuaries). Similarly, a combination of Class 1 and Class 2 inland waterbody segments are pollutant sources for the Bay (see Figure 4). Assuming equal importance of embayment impact among these inland segments, implementation activities affecting Class 1 inland segments may be a higher priority than those affecting Class 2 inland segments, since Class 1 inland waters are to "remain in their natural state as nearly as possible with an absolute minimum of pollution from any human caused source."

Designated uses of Class 1 inland waters such as "protection of native breeding stock" and "aesthetic enjoyment" don't extend to Class 2 inland waters. Thus, as with the embayment example above, the relative importance of upstream/downstream segment interaction upon Class 1 natural state maintenance, pollution minimization, native breeding stock, and aesthetic enjoyment could be factors for prioritizing implementation activities that affect inland waters. However, when assuming equal importance of Class 1 impact among these upstream/downstream segments, implementation activities affecting Class 1 inland segments may not necessarily be a higher priority than those affecting Class 2 inland segments. This is based on the fact that Hawaii stream ecosystems and the amphidromous organisms that travel through them don't recognize human divisions between Class 1 and Class 2 waters. Thus factors for prioritizing implementation activities throughout the watershed should also emphasize habitat quality, biotic integrity, and related existing uses (such as support for traditional and customary native Hawaiian beliefs, values, and practices and for other "reasonable and beneficial uses" and instream uses protected under the State Water Code (Hawai'i Revised Statutes Chapter 174C; State of Hawai'i, 2004).

8.2. Land ownership

Less than 15 landowners control a large majority of the Hanalei watershed area and riparian property. Detailed planning efforts can use the relative magnitude and importance of each landowner's water quality impacts as factors for prioritizing implementation activities. This can be further refined according to each landowner's interest and capability (resources). Initial analysis from this perspective suggests that the State of Hawaii Department of Land and Natural Resources (DLNR), Princeville corporations, U.S. Fish and Wildlife Service (USFWS), Kamehameha Schools, and Waikoko Land Corp. are the most critical landowners for supporting implementation activities, due to the large areas they control and their potentially greater ability to access private and public funding and technical resources.

At this stage in the TMDL implementation process, DOH's role is mainly to identify a wide range of implementation alternatives, not necessarily to select them. As explained on our response to public comments on the draft TMDL, DOH is neither encouraging nor discouraging landowners from imposing restrictions on farmers in their agricultural leases. A multitude of public and private landowners and their tenants; other public and private watershed users; and various local, state, and federal regulatory authorities are all responsible for achieving the State's water quality goals. The purpose of our Implementation Framework is to identify all the responsible parties, their relationships with each other, and the possible ways they could affect and effect TMDL implementation. It is not to pass judgment on how they should or should not conduct these relationships, which is more appropriately the role and responsibility of community-driven TMDL implementation planning.

8.3. Regulatory and management authority

The scope of regulatory and management authority available to support implementation activities varies across land use designations and agency responsibilities. Although we believe it is our duty to fully identify potential implementation mandates (including those largely beyond DOH control, such as legislation, approval and permitting conditions by other agencies, lease conditions, and third-party lawsuits), DOH is not recommending any particular mandates in Hanalei at this time. Instead, we advocate a community-driven adaptive approach to implementing nonpoint source load allocations based on TMDL decisions, other watershed planning results, and local knowledge and experience. Detailed planning efforts, such as the upcoming Watershed Based Plan for Hanalei, can identify how particular authorities can be used to achieve specific results. Public landowners, when regulating and managing their own lands (in this case, primarily DLNR, USFWS, State of Hawaii Department of Transportation, and County of Kauai), may be the most viable group for supporting implementation activities from this perspective. For example, how can the U.S. Fish and Wildlife Service coordinate implementation activities with its regulation of agricultural leases, management of critical and refugial habitats, and planning of species conservation and recovery? How can DLNR coordinate implementation activities with its management of the State Forest Reserve? Initial analysis of this last question might, for example, compare the high vegetation resource value of native forest areas with the draft management guidelines (e.g., "resource management is not a principle objective of game animal management") for some of these same areas, as illustrated below in Figure 20 and further documented at DLNR's website (www.state.hi.us/dlnr/dofaw/guidelines/mg_jw03/index.html).

As co-trustees of publicly-owned water resources, DLNR, DOH, County of Kauai, and other government regulators and managers can also exert their influence across land ownership boundaries to enable and promote implementation activities. The State Water Code (HRS 174C-3) provides a mandate for DLNR's Commission on Water Resource Management to achieve water quality objectives through various regulatory actions (e.g. water reservations, instream flow standards, water management areas, water use permits, and stream channel alteration permits) and complaint/dispute resolution and planning processes. In particular, the Hawaii Water Plan can link these state objectives with county objectives via the Kauai County Water Use and Development Plan Ordinance (www.hawaii.gov/dlnr/cwrm/planning/index.htm).

How can DLNR's regulation and management of lands in the Conservation District be linked with DOH water quality objectives? In one example, the present sandwiching of a Class 2 segment of Hanalei Stream between two Class 1 segments (the lower in the Hanalei National Wildlife Refuge, the upper in the Newcomb's snail critical habitat) could be eliminated by extending the Preservation Subzone of the Conservation District to cover the existing Class 2 segment (see Figure 4) . A similar linkage could be achieved by extending the Preservation Subzone to cover all critical habitat areas. In a third scenario where the Preservation Subzone isn't extended, DOH could perhaps achieve class 1-level protection for the class 2 segment by designating it as an Outstanding National Resource Water.

DOH water quality management and water pollution control efforts overlap and interface with several County of Kauai implementation mechanisms. The Kauai General Plan (e.g. Chapter 3, Caring for Land, Water and Culture) can be used to link broad planning objectives across jurisdictions (www.kauai.gov/Default.aspx?tabid=130). The Department of Budget and Finance (www.kauai.gov/default.aspx?tabid=162) finds and administers the funding to achieve these objectives, and the Department of Public Works Engineering Division (www.kauai.gov/default.aspx?tabid=65) is where detailed water quality strategies and tactics are developed and used for enforcement (Grubbing, Grading and Stockpiling Ordinance; Flood Ordinance), operations (Storm Water Management Program), and planning and development purposes (Roads and Drainage Facilities Design and Construction Program; Subdivisions/Consolidations, Zoning, and Use Permit Review Program).

As implementation proceeds, we recognize that county governments have a special role in setting public policy for land uses. We note that water quality standards also embody an important public policy, to protect the designated uses of state waters, and standards-based TMDLs are a required vehicle for implementing this statewide policy. Given that both state and county governments have public trust duties to protect state waters, TMDLs should be an important tool and consideration in water quality project assessment and land use decisionmaking.

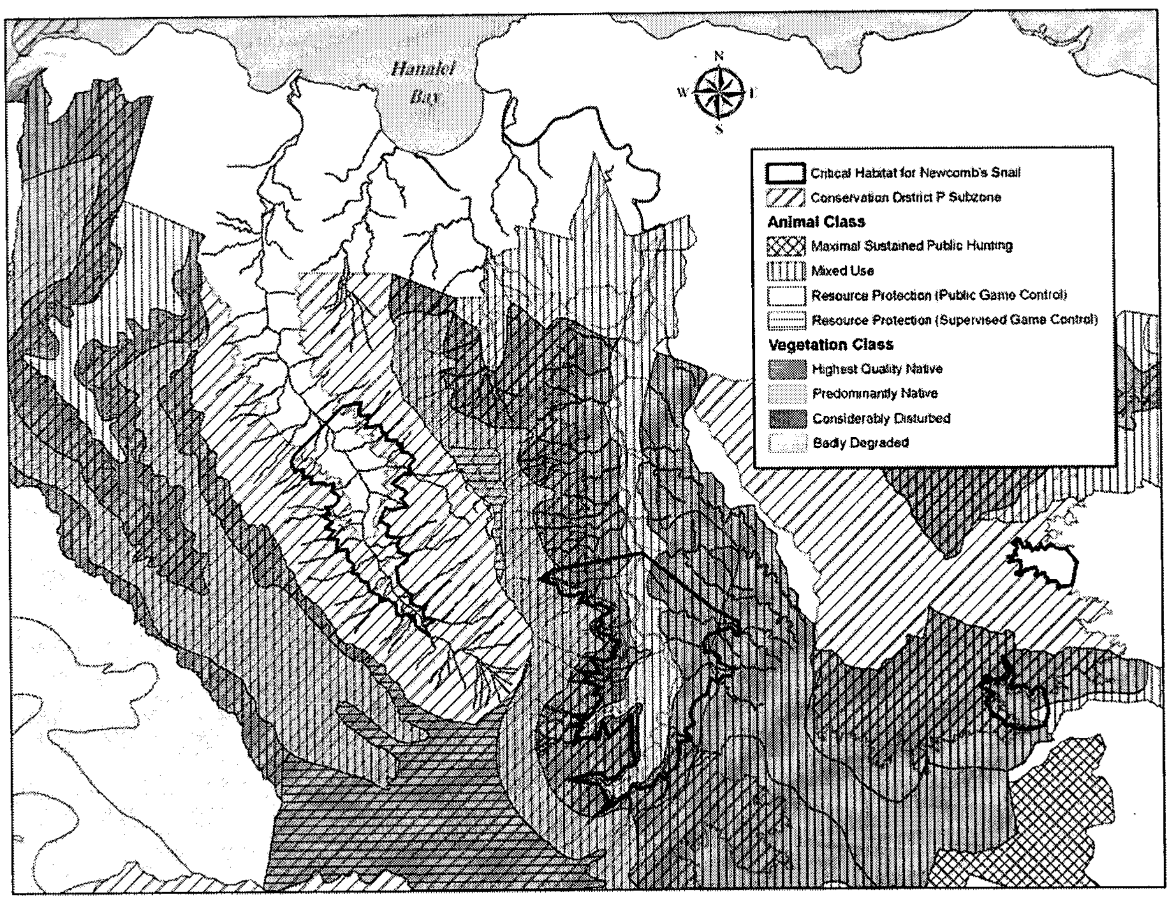


Figure 20. Overlapping Regulatory and Management Frameworks in the Hanalei Bay Watershed

8.4. Land cover and degrading activities (problem areas)

Water quality monitoring data are generally not sufficient to fully characterize all sources of bacteria, sediment, and nutrients in the watersheds draining to impaired waterbodies Analyses of the available data, for example as presented in Appendix C (Relative Land Cover Loadings), provides a starting point for identifying source areas that can be prioritized for further examination. These major source categories are considered controllable for TMDL implementation purposes, and the potential effectiveness of implementation activities can be simulated for an array of management scenarios. Generally, the higher the percentage of a particular land cover class the higher the pollutant load contribution. Additional information to consider in identifying the type and location of specific implementation activities includes the relationship between site characteristics (such as slope, soil type, vegetation type, and disturbance type and intensity) and the loading characteristics of various pollutants.

Initial results suggest that the main pollutant sources are open areas (scrub/shrub and evergreen forest land cover types), runoff from agriculture, and waterbird impoundments. Among these, the bulk of the bacterial source areas appear to include wildlands and wetlands in the larger watersheds (Hanalei, Waioli, Waipa) and cultivated lands in Waikoko. Management strategies that address TSS are likely to also reduce total N and total P, and the main source areas for sediment appear to be unmanaged lands in the larger watersheds. Cultivated lands in Waikoko are suggested as a major contributor of total N and total P, and cultivated lands throughout the watershed seem to represent the main source of ammonia and nitrate nitrogen.

Three potential causes of water quality degradation are prominent in various parts of the watershed and deserve additional attention in the detailed planning process. Most of the Hanalei watershed is serviced by cesspools or septic systems, and the Hanalei Watershed Hui, EPA, and DOH placed an early emphasis on onsite wastewater disposal systems. the Hui has formed a Wastewater Working Group to working with Kauai County to solve these problems with the County. Existing County of Kauai plans call for improved wastewater treatment, and government agencies can acquire low interest loans from DOH's State Revolving Fund (SRF) to assist with upgrading cesspools to septic system.

Invasive species are an ongoing threat to the biological integrity of the waterbodies, and DLNR strategies for their control (State of Hawaii Aquatic Invasive Species Management Plan, www.hawaii.gov/dlnr/dar/pubs/ais_mgmt_plan_final.pdf) could perhaps be integrated with the DOH mission to protect and restore the biological, chemical, and physical integrity of state waters. Feral pigs are widely believed to accelerate erosional processes and act as sources of nutrient and bacterial input. DLNR's recent Plan to Reduce the Statewide Feral Pig Population (www.hawaii.gov/dlnr/reports/FW07-Feral_Pig_Report%20_HCR_98_SD1-06_.pdf) is one reference for planning specific pig control activities.

Much of the information above is based upon Section 5 (Source Analysis) and provides a relative breakdown of pollutant contribution by landcover class. Generally, the higher the percentage of a particular land cover class the higher the overall pollutant load contribution. Further, in the TMDL allocation scenarios each land cover class was given